November 1895.] [No. 62.

PROCEEDINGS
OF THE
PHYSICAL SOCIETY
OF LONDON.

VOL. 13. PART 12.

OFFICERS AND COUNCIL.

President.
Capt. W. de W. Abney, R.E., C.B., D.C.L., F.R.S.

Vice-Presidents who have filled the Office of President.
Dr. J. H. Gladstone, F.R.S.
Prof. G. C. Foster, F.R.S.
Prof. W. G. Adams, M.A., F.R.S.
Lord Kelvin, D.C.L., LL.D., P.R.S.
Prof. R. B. Clifton, M.A., F.R.S.
Prof. A. W. Reinold, M.A., F.R.S.
Prof. W. E. Ayrton, F.R.S.
Prof. G. F. Fitzgerald, M.A., F.R.S.
Prof. A. W. Rücker, M.A., F.R.S.

Vice-Presidents.
Walter Baily, M.A.
Maj.-Gen. E. R. Festing, R.E., F.R.S.
Prof. J. Perry, D.Sc., F.R.S.
G. Johnstone Stoney, M.A., F.R.S.

Secretaries.
T. H. Blakesley, M.A., M.I.C.E.
H. M. Elder, M.A.

Treasurer.
Dr. E. Atkinson.

Demonstrator and Librarian.
C. Vernon Boys, F.R.S.

Other Members of the Council.
Shelford Bidwell, M.A., LL.B., F.R.S.
Prof. W. Crookes, F.R.S.
L. Fletcher, M.A., F.R.S.
R. T. Glazebrook, M.A., F.R.S.
G. Griffith, M.A.
Prof. O. Henrici, Ph.D., F.R.S.
Prof. G. M. Minchin, M.A., F.R.S.
James Swinburne.
Prof. S. P. Thompson, D.Sc., F.R.S.
Prof. S. Young, D.Sc., F.R.S.

Editor.
J. Swinburne.
66 *Victoria Street*, S.W.

Abstractors.
R. Appleyard.
E. H. Barton, D.Sc.
R. E. Baynes, M.A.
H. Borns, Ph.D.
G. H. Bryan, M.A., F.R.S.
S. H. Burbury, M.A., F.R.S.
C. V. Burton, D.Sc.
J. W. Capstick, M.A., D.Sc.
A. Daniell, M.A.
T. E. Ewan.
E. E. Fournier d'Albe.
Prof. A. Gray, M.A.
A. Griffiths, B.Sc.
J. L. Howard, D.Sc.
Prof. D. E. Jones, B.Sc.
R. A. Lehfeldt, B.A., B.Sc.
T. Preston, M.A.
W. G. Rhodes, M.Sc.
S. Rideal, D.Sc., F.I.C.
E. C. Rimington.
J. W. Rodger.
G. F. C. Searle, M.A.
S. Skinner, M.A.
W. E. Sumpner, D.Sc.
A. P. Trotter.
F. T. Trouton, D.Sc.
W. Watson, B.Sc.
W. C. D. Whetham, M.A.
L. R. Wilberforce, M.A.

Reporter.
W. Watson, B.Sc.

LONDON:
TAYLOR AND FRANCIS, RED LION COURT, FLEET STREET.

Price to Non-Members, ~~Two Shillings & Sixpence~~

Page
LII. The Thermal Properties of Isopentane. By SYDNEY YOUNG, D.Sc., F.R.S., University College, Bristol (*continued*) .. 605

NAME INDEX (ABSTRACTS).

Amagat, 428.
Armagnat, 443.
Aschkinass, 436.
Ascoli, 450.
Bakker, 429.
Bauer, 447, 450.
Berthelot, 441.
Bigelow, 453.
Bigourdan, 431.
Boltzmann, 448.
Bouchard, 456, 456.
Bradley, 449.
Bredig, 454.
Briggs, 445.
Cattaneo, 440.
des Coudres, 454, 455.
Deslandres, 431.
Ditte, 442.
Dumas, 433.
Einthoven, 433.
Folgheraiter, 452.
Gautier, 433.
Gay-Lussac, 454.
Grotrian, 450.
Guillaume, 436.
Guthe, 445.
Hertz, 448.
van't Hoff, 437.
Hospitalier, 436.
Jahn, 455.
Janssen, 431.
Julius, 432.
Kohlrausch, 445.
Krakau, 434.
van Laar, 437.
Laplace, 432.
Lebedew, 447.
Lehmann, 445.
Lévy, 431.
Leyst, 442.
Lhuillier, 443.
Lippmann, 433.
Lumière, 434.
Magnanini, 456.
McConnel, 429.
Michelson, 433.
Moissan, 433, 440.
Morley, 433.
Mügge, 429.
Natanson, 438.
Neyreneuf, 439.
Olszewski, 437.
Ostwald, 454, 456.
Ouvrard, 456.
Pellat, 439.
Pensky, 431.
Poiseuille, 432.
Regnault, 433, 434.
Rodet, 440.
Röntgen, 430.
Rudolphi, 437, 454, 455.
Rühlmann, 442.
Schmidt, 442.
Schweidler, 432.
Steinmetz, 450.
Stortenbeker, 434.
Sutherland, 432.
Tait, 429.
Tammann, 428, 430.
Thierry, 431.
Thomson, 447.
de la Tour, 439.
Troost, 456, 456.
Villari, 434.
van der Waals, 432.
Weiss, 443.
Wesendonck, 434.
Wirtz, 436.
Wood, 427.
Zamboni, 454.
Zsigmondi, 436.

WILLIAMS AND NORGATE,

14 HENRIETTA STREET, COVENT GARDEN, LONDON;
20 SOUTH FREDERICK STREET, EDINBURGH;
AND 7 BROAD STREET, OXFORD,

PUBLISHERS AND IMPORTERS OF
FOREIGN SCIENTIFIC BOOKS.

Largest Stock of Foreign Works, especially in the Departments of Physics, Electricity, Microscopy, Optics, etc.

MOST RECENT IMPORTANT CONTINENTAL PUBLICATIONS.

Arens (Fr.). Die Erzeugung der Electricität. 6*d*.

Behrens (H.). Anleitung zur mikrochemischen Analyse. Mit einem Vorwort von Prof. S. Hoogewerff in Delft. 224 Seiten mit 92 Figuren in Text. 8vo. 6*s*. net.

Biedermann (W.). Elektrophysiologie. 1te Abtheilung. Mit 136 Abbildungen. 440 Seiten. 8vo. 9*s*. net.

Brunhes (B.). Cours élémentaire d'électricité. Paris, 1895. 8vo. Avec 137 fig. 4*s*. 6*d*. net.

Dammer (Dr. O.). Handbuch der chemischen Technologie. Unter Mitwirkung von Direktor Th. Beckert, Dr. Bender, Dr. Benedikt, Dr. Börnstein u. A. herausgegeben. 2ter Band. Mit 235 in den Text gedruckten Figuren. gr. 8vo. 20*s*. net.

Demarçay (E.). Spectres électriques. Paris, 1895. 4to. Atlas de 10 pl. 20*s*. net.

Dumont (G.) et **Baignères** (G.). Étude sur le transport de l'énergie à grande distance par l'électricité. Paris, 1895. 8vo. VI, 114 pp. Avec 77 fig. 5*s*. net.

Fleming (J. A.). Electrical Laboratory Notes and Forms, elementary and advanced. London, 1895. 8vo. 250 pp. 12*s*. 6*d*. net.

Frick (Dr. J.). Physikalische Technik speciell Anleitung zur Ausführung physikalischer Demonstrationen und zur Herstellung von physikalischen Demonstrations-Apparaten mit möglichst einfachen Mitteln. 6. Umgearbeitete und vermehrte Auflage. Von Dr. Otto Lehmann. Vol. II. Gr. 8vo. XXVI. u. 1054 Seiten. Mit 1016 eingedruckten Holstichen und 3 Tafeln. 20*s*. net.

Hospitalier (E.). Recette de l'électricien. Colligées et mises en ordre par E. Hospitalier. 3*s*. 6*d*. net.

Jahn (H). Grundriss der Electrochemie. Vienna. 8*s*. 6*d*. net.

Jahrbuch der Elektrochemie. Berichte über die Fortschritte des Jahres 1894.—Im wissenschaftlichen Theile bearbeitet von Dr. W. **Nernst**, im technischen Theile von Dr. W. **Borchers.** I. Jahrgang. 274 Seiten. gr. 8vo. 10*s*. net.

Klimpert (Richard). Wiederholungsbuch zum Studium der Allgemeinen Physik und elementaren Mechanik. Dresden, 1895. 8*s*. net.

Kolbe (Bruno). Einführung in die Electricitätslehre. Band II. Dynamische Elektricität. Mit 75 in den Text gedruckten Holzschnitten. 187 Seiten. 8vo. 3*s*. net.

Laffargue (J.). Les Applications mécaniques de l'énergie électrique. In-12, avec 320 fig. Paris. 2*s*. 6*d*. net.
Forme le No. 3 de la 'Bibliothèque électrotechnique.'

Lehmann (Dr. Otto). Elektricität und Licht. Einführung in die messende Elektricitätslehre und Photometrie. 7*s*. net.

Lüpke (Rbt.). Grundzüge der wissenschaftlichen Elektrochemie auf experimenteller Basis. Berlin, 1895. J. Springer. VIII, 150 pp. Mit 46 fig. 3*s*. net.

Oppenheimer (C.). Grundriss der organischen Chemie. Berlin, 1895. 8vo. VII, 130 pp. 2*s*. 6*d*. net.

Poincaré (H.). Cours de Physique mathématique. Théorie analytique de la propagation de la chaleur. Paris, 1895. 8vo. 316 pp. Avec fig. 8*s*. 6*d*. net.

Propaedeutik Physikalisch-chemische von Prof. Dr. **Griesbach**. Part I. 6*s*. net.

Schwartze (Th.). Die Lehre von der Elektricität und deren praktische Verwendung. Mit 153 in den Text gedruckten Abbildungen. 543 Seiten. 8vo. 10*s*. net.

Schwerebestimmungen Relative durch Pendelbeobachtungen. Ausgeführt durch die k. und k. Kriegs-Marine in den Jahren 1892–94. Herausgegeben vom k. und k. Reichs-Kriegsministerium (Marine-Section). Umfang: 39½ Bogen Lex.-8vo. (522 Seiten Tabellen und 5 Tafeln). Geh. 18*s*. 6*d*. net.

Vogel (Dr. Fr.). Theorie electrolytischer Vorgänge. Halle. 5*s*. net.

Weierstrass (K.). Mathematische Werke. Herausgegeben unter Mitwirkung einer von der königl. preussischen Akademie der Wissenschaften eingesetzten Commission. II. Bd. Abhandlungen II. Berlin, 1895. 4to. VI, 362 pp. 21*s*. net.

Zickler (Prof. Karl). Das Universal-Elektrodynamometer. Mit 8 in den Text gedruckten Figuren. 32 Seiten. 8vo. 1*s*. net.

CATALOGUES AND MONTHLY LISTS OF FOREIGN BOOKS ON APPLICATION.

PERIODICALS SUPPLIED WITH THE UTMOST REGULARITY AND AT VERY MODERATE TERMS.

CAMBRIDGE UNIVERSITY PRESS.

The Scientific Papers of the late Prof. J. Clerk Maxwell. Edited by W. D. Niven, M.A., formerly Fellow of Trinity College. In 2 vols. Royal 4to. £3 3*s*. net.

Mathematical and Physical Papers. By Lord Kelvin (Sir W. Thomson), LL.D., D.C.L., F.R.S., Professor of Natural Philosophy in the University of Glasgow. Collected from different Scientific Periodicals from May 1841 to the present time. Demy 8vo. Vol. I., 18*s*. Vol. II., 15*s*. Vol. III., 18*s*.

Mathematical and Physical Papers. By Sir G. G. Stokes, Sc.D., LL.D., F.R.S., Lucasian Professor of Mathematics in the University of Cambridge. Reprinted from the Original Journals and Transactions, with Additional Notes by the Author. Demy 8vo. Vol. I., 15*s*. Vol. II., 15*s*. [*Vol. III. in the Press.*

A Treatise on Analytical Statics. By E. J. Routh, Sc.D., F.R.S., Fellow of the University of London, Honorary Fellow of Peterhouse, Cambridge. Demy 8vo. Vol. I., 14*s*. Vol. II., 10*s*.

A Treatise on the Mathematical Theory of Elasticity. By A. E. H. Love, M.A., Fellow of St. John's College, Cambridge. 2 Vols. Demy 8vo. Vol. I., 12*s*. Vol. II., 12*s*.

History of the Theory of Elasticity, and of the Strength of Materials, from GALILEI to the PRESENT TIME. By the late I. Todhunter, Sc.D., F.R.S. Edited and Completed by Prof. Karl Pearson, M.A.

Vol. I. GALILEI to SAINT-VENANT, 1639–1850. Demy 8vo. 25*s*.
Vol. II. SAINT-VENANT to LORD KELVIN (Sir William Thomson). Demy 8vo, in 2 Parts. 30*s*.

Hydrodynamics. By Horace Lamb, M.A., F.R.S., formerly Fellow of Trinity College, Cambridge, Professor of Mathematics in the Owens College, Manchester. Demy 8vo. 20*s*. net.

Extract from Preface.—"This book may be regarded as a second edition of a *Treatise on the Mathematical Theory of the Motion of Fluids,* published in 1879; but the additions and alterations are so extensive that it has been thought proper to make a change in the title."

Electricity and Magnetism. By J. J. Thomson, M.A., Cavendish Professor of Experimental Physics in the University of Cambridge. Crown 8vo. [*In the Press.*

The Steam-Engine and other Heat Engines. By J. A. Ewing, M.A., F.R.S., M.Inst.C.E., Professor of Mechanism and Applied Mechanics in the University of Cambridge. Demy 8vo, with Illustrations, 15*s*.

Engineering Record, New York.—"Prof. Ewing's treatise furnishes a valuable addition to the literature of heat engines. . . . The matter is presented in well selected and attractive language, and what would otherwise be dry reading is made unusually interesting . . . . On the whole, Prof. Ewing has brought out a treatise which is admirable, so far as its scope extends. Its applications are mainly on the lines of English practice, and naturally so; but its exposition of the principles of steam-working are sound, and they will prove of undoubted assistance to every engineering student, whether American or English."

A Treatise on Elementary Dynamics. By S. L. Loney, M.A., Fellow of Sidney Sussex College. Second Edition, enlarged. Crown 8vo, 7*s*. 6*d*. Solutions to the Examples, 7*s*. 6*d*.

"This is one of the best and most complete treatises on elementary dynamics which have come before us for a long time. The principles of the subject are stated with great clearness, and the illustrative examples are very appropriate."—*Athenæum.*

A Treatise on Elementary Hydrostatics. By J. Greaves, M.A., Fellow and Lecturer of Christ's College, Cambridge. Crown 8vo. 5*s*.

"A brief examination of this treatise is sufficient to allow us to form a favourable opinion of its contents. Nearly every proposition or description shows that the author is a thorough master of his subject, and, what is also of equal importance, can impart his knowledge to his readers in language both concise and fresh."—*Nature.*

CAMBRIDGE NATURAL SCIENCE MANUALS.

PHYSICAL SERIES.

General Editor—R. T. Glazebrook, M.A., F.R.S., Fellow of Trinity College, Cambridge, Assistant Director of the Cavendish Laboratory.

Mechanics and Hydrostatics. An Elementary Text-book, Theoretical and Practical, for Colleges and Schools. By R. T. Glazebrook, M.A., F.R.S. Crown 8vo.
Part I. DYNAMICS. 4*s*. Part II. STATICS. 3*s*. Part III. HYDROSTATICS (nearly ready).

Educational Review.—"In detail it is thoroughly sound and scientific. The work is the work of a teacher and a thinker, who has avoided no difficulty that the student ought to face, and has, at the same time, given him all the assistance that he has a right to expect. We hope, in the interests both of experimental and mathematical science, that the scheme of teaching therein described will be widely followed."

Heat and Light. By R. T. Glazebrook, M.A., F.R.S. Crown 8vo. 5*s*. And separately, HEAT, 3*s*.; LIGHT, 3*s*.

Nature.—"Teachers who require a book suitable for the class-room and the laboratory would do well to adopt Mr. Glazebrook's work."

London: C. J. CLAY & SONS,
Cambridge University Press Warehouse, Ave Maria Lane.

The greater portion came over below 32°, but the temperature finally rose to 56°.

The isopentane, which in addition to the higher-boiling impurity contained a small quantity of a very volatile substance, was then fractionated ten times, and was finally collected in two fractions both of which boiled quite constantly at 27°·45 under a pressure of 748·5 millim.

Proofs of Purity of the Isopentane.

It seemed at first rather doubtful—from its method of formation and from its behaviour with sulphuric and nitric acids—whether the isopentane could be obtained in a pure state; but the impurities were removed without much difficulty by fractional distillation, and the following evidence leaves no doubt that the substance was satisfactorily purified:—

1. The two fractions boiled at precisely the same temperature and both quite constantly.
2. The specific gravities of the two fractions at 0° were practically identical (0·63925 and 0·63922).
3. The critical temperatures and pressures of the two fractions were in very close agreement (see p. 609).
4. The vapour-pressures of both fractions were determined at a great number of different temperatures and agreed very well together.
5. The vapour-pressure was found to be entirely independent of the relative volumes of liquid and vapour. The experimental results at two temperatures, 90° and 140°, have already been published in a paper read before the Physical Society (Phil. Mag. Dec. 1894, p. 569; *ante*, p. 271). The object of the paper was to show that the vapour-pressure *of a pure substance* at any temperature is independent of the relative volume of liquid and vapour; but since it is well known that the vapour-pressure of an impure liquid does depend on the volume*, the invariability of the vapour-pressure in the

---

* It is true that in a limited number of special cases a particular mixture of two substances at a given temperature exerts a lower vapour-pressure than any other mixture (*e. g.* formic acid and water), or a higher vapour-pressure (*e. g.* propyl alcohol and water), and that the vapour-pressure of such a mixture at that temperature is independent of the relative volumes of liquid and vapour; also that such a mixture

case of my specimen of isopentane may perhaps be adduced as evidence in favour both of the purity of this particular substance and of the behaviour of pure substances in general. In any case the other proofs of purity appear to be sufficient.

6. In the course of the determinations of the volume of a gram of vapour with a modified Hofmann's vapour-density apparatus the vapour-pressure was measured at a few temperatures, and a comparison of these pressures with those read from the curves constructed from the data obtained by the dynamical method shows that the agreement is satisfactory.

Vapour-Pressure.

Temperature.	Statical.	Dynamical.	Δp.	Δt.
10°·6	401·0	400·0	+1·0	−0·05
10·85	405·6	403·95	+1·65	−0·1
11·05	406·1	407·15	−1·05	+0·05
16·55	499·6	503·6	−4·0	+0·2

7. The agreement of the boiling-point, specific gravity, vapour-pressures at high temperatures, and critical constants with those of a specimen of isopentane prepared by G. L. Thomas and myself from amyl iodide.

Boiling-Point.

The isopentane was always distilled over phosphorus pentoxide immediately before being used for any determination, and there are thus a considerable number of observations of the boiling-point. They are given in the table below, together with the boiling-points corrected to 760 millim. pressure.

---

would boil at a constant temperature and distil unchanged in composition under that pressure; but it has been found in such cases that the composition of the mixture which has a maximum or minimum vapour-pressure (and a constant boiling-point) differs to some extent at different temperatures (and pressures). In such a case, therefore, it might be found at a certain temperature that the vapour-pressure of the mixture was independent of the relative volumes of liquid and vapour, but it is in the highest degree improbable that a similar result would be obtained with the same mixture at a widely different temperature.

The value of dp/dt at the boiling-point = 26·2 millim. The boiling-point, calculated from the constants for Biot's formula, is 27°·95.

Fraction A.			Fraction B.		
Pressure.	Temperature.		Pressure.	Temperature.	
	Observed.	Corrected to 760 mm.		Observed.	Corrected to 760 mm.
745·4	27°·3	27·85	748·5	27·45	27·9
748·5	27·45	27·9	751·1	27·55	27·9
749·0	27·55 *	27·95	751·2	27·6	27·95
751·2	27·6	27·95	751·5	27·65 *	27·95
753·5	27·7	27·95	752·4	27 65 *	27·95
758·9	27·9 *	27·95	759·1	27·95 *	28·0
759·1	27·95 *	28·0	761·7	28·0	27·95
761·9	28·0	27·95			
765·3	28·15	27·95		Mean	27·95
	Mean	27·95			

* The temperatures marked with an asterisk were determined with a Geissler's normal thermometer.

Boiling-Points by other Observers.

	Name.	Reference.	Pressure.	B.P.	B.P. reduced to 760 millim.
1.	Schmidt	*Annalen*, cclxvi. p. 282.	760·7	31°–33°	31°–33°
2.	Pawlewski	*Ber.* xvi. p. 2633.	760	..	31
3.	Schiff	*Annalen*, ccxx. p. 87.	760	..	30·5–31·5
4.	Perkin	Trans. Chem. Soc. xlv. p. 445.	760	..	29–32
5.	Thorpe and Rodger	Phil. Trans. clxxxv. A, p. 453.	760	..	30·4
6.	Schorlemmer	Proc. Roy. Soc. xvi.	760	..	30
7.	Goldstein	J. Russ. Chem. Soc. 1882, p. 45.	760	..	30·5
8.	Beilstein and Kurbatow ..	*Ber.* xiv. p. 1620.	..	..	30
9.	Wurtz	*Annalen*, cxxviii. p. 229.	..	..	28–30
10.	Pelouse and Cahours ..	*Jahresb.* xvi. p. 527.	..	..	30
11.	Lachowitz	*Annalen*, ccxx. p. 188.	..	..	29–30
12.	Frankland	Trans. Chem. Soc. iii. pp. 31 & 481.	734	30	31
13.	Just	*Annalen*, ccxx. p. 146.	..	..	30
14.	Landolt and Jahn .	*Zeit. Phys. Chem.* x. p. 290.	760	..	28
15.	Altschul	*Ibid.* xi. p. 590.	760	..	28

Mr. J. W. Rodger has kindly informed me that he has prepared specimens of isopentane from amyl iodide obtained from both Scotch and

Irish samples of amyl alcohol, and that they boiled within 0°·05 and 0°·02 respectively. The observed boiling-points were :—

From Irish amyl alcohol....	28°·04,
„ Scotch „ „	28°·01.

---

1. Obtained from Trommsdorff (from American petroleum) dried with phosphorus pentoxide and fractionated. Schmidt states that the sample contained a considerable quantity of normal pentane.
2. Source not stated.
3. Separated from commercial amylene by treatment with sulphuric acid diluted with its own weight of water. Residue treated with concentrated sulphuric acid until the acid was no longer coloured. Distilled and heated to 130° with sodium.

4–6. Specimens prepared by Schorlemmer from petroleum.

8. From Caucasian petroleum.
9. From crude amylene by action of bromine.
10. From American petroleum.
11. From petroleum from Galicia.
12. By action of zinc and water on amyl iodide.
13. By action of zinc and hydrochloric acid on amyl iodide.

14, 15. Separated from amylene by means of bromine. The substance is called "pentane."

As these observations of the boiling-point of isopentane, with the exception of those of Landolt and Jahn, Altschul, and Rodger, are considerably higher than mine, a specimen of isopentane was prepared by Thomas and myself from amyl iodide; the method of preparation and the observations of the boiling-point, specific gravity, and critical temperature and pressure are given in a separate paper. These observations agreed perfectly with those described in this paper. The boiling-point was 27°·95 at 760 millim.

Specific Gravity.

The specific gravity of each fraction was determined at two different temperatures by Sprengel's method as modified by Perkin. The weighings were reduced to a vacuum.

Temperature.	Fraction A.	Fraction B.
0°	0·63925	0 63922
14°·4	0·62514	
13°·45	...	0·62614

The specific gravity at 0° of the sample prepared by Thomas and myself was ·63935.

Specific Gravities by other Observers.

Name.	Sp. gr. at t°.		Sp. gr. at 0°.
Schiff	0·6282	at 13·7°	0·6416
Pelouse and Cahours .	0·628	,, 18	0·6458
Frankland	0·6413	,, 11·2	0·6524
,, ...	0·6385	,, 14·2	0·6526
Just	0·6375	,, 13/13	0·6500
Bartoli and Stracciati *	0·6402	,, 0	0·6402
Landolt and Jahn ...	0·62656	,, 14·3	Mean ... 0·64058†
,, ,, ...	0·62472	,, 16·2	
,, ,, ...	0·62278	,, 18·2	
,, ,, ...	0·62074	,, 20·0	
Perkin	0·62479	,, 15/15	0·63893
,, ...	0·61590	,, 25/25	0·63888

The specific gravities at 0° were calculated from the observations at higher temperatures by means of the formula

$$D_t = 0{\cdot}63923 - 0{\cdot}0_3958\,t - 0{\cdot}0_5 13\,t^2.$$

This formula agrees very well with my experimental results up to 60°.

My observations agree very well with Perkin's, although the specimen examined by him boiled between 29° and 32°. It was prepared by Schorlemmer, and, no doubt, contained some normal pentane, the specific gravity of which differs but slightly from that of isopentane.

Critical Constants.

		Fraction A.		Fraction B.	
		Temperature.	Pressure.	Temperature.	Pressure.
		°	millim.	°	millim.
With Aniline vapour as jacket ...	(1)	187·75	25020	187·75	25000
	(2)	187·8	25020		
,, Quinoline ,, ,, ...	(1)	187·85	25030	187·85	25020
	(2)	187·9	25020		

---

* *Beiblätter*, ix. p. 697.

† Landolt and Jahn calculate the specific gravity at 0° as 0·64116.

The mean values are :—

Critical temperature	187°·8
Critical pressure	25015 millim.

The sample prepared by Thomas and myself gave the following results :—

Critical temperature	187°·8.
Critical pressure	25030 millim.

The critical volume of a gram, calculated by the method of Cailletet and Mathias from the mean densities of liquid and saturated vapour at lower temperatures, is 4·266 cub. centim.

Critical Constants by other Observers.

	Temperature. °	Pressure. millim.
Schmidt	193·0	
Pawlewski . .	194·8	
Altschul	187·1	25300

It may be pointed out that Schmidt's sample of isopentane contained some normal pentane, which would raise the critical temperature, and that Pawlewski's observations of critical temperature are in most cases somewhat higher than mine. On the other hand, those of Altschul agree well in the few cases that can be compared. They are given in the table below :—

	ALTSCHUL.		YOUNG.	
	Temperature.	Pressure.	Temperature.	Pressure.
Normal Hexane ...	° 234·5	atm. 30·0	° 235·0	atm. 29·76
Benzene..............	290·5	50·1	288·5	47·9
Chlorobenzene	362·2	......	359·3 *	......

* Corrected for error in the boiling-point of mercury.

Vapour-Pressures at Low Temperatures.

The vapour-pressures at temperatures below the boiling-point under atmospheric pressure were determined by the dynamical method of Ramsay and Young (Trans. Chem. Soc. xlvii. p. 43).

For temperatures below 0° a thermometer by Warmbrunn, Quilitz, & Co. of Berlin was employed; it had been standardized by the Physikalisch-Technische Reichsanstalt. The effect of alteration of pressure on the readings of the thermometer was ascertained and allowed for, and the very small correction for the heated column of mercury in the stem of the thermometer was also applied.

The logarithms of the vapour-pressures were mapped against the temperatures, and the values at each ten degrees were read from the curve. The observed pressures are given in the table below, and the pressures at even temperatures in the table on p. 613.

Vapour-Pressures at Low Temperatures.

Temperature.	Pressure.	Temperature.	Pressure.	Temperature.	Pressure.	Temperature.	Pressure.
Sample A (1).							
°	millim.	°	millim.	°	millim.	°	millim.
−31·83	52·7	−26·18	71·85	−12·86	143·4	−3·48	221·6
−31·38	53·95	−23·59	83·2	−12·71	144·15	−0·81	249·7
−30·29	57·5	−23·01	84·9	− 9·45	168·4	+0·10	259·1
−28·88	62·3	−20·45	98·0	− 6·53	193·05		
−26·53	71·0	−16·13	122·1	− 6·45	193·5		
Sample A (2).							
+2·55	290·5	11·65	422·5	20·9	587·6		
5·6	330·8	14·9	473·3	23·35	642·5		
9·0	377·3	17·95	529·4	25·95	705·2		
Sample B (1).							
−31·08	54·75	−25·91	73·45	−14·24	134·05	−4·82	208·85
−29·47	60·1	−22·33	88·9	−10·38	161·35	−2·44	232·3
−29·04	61·75	−18·06	110·95	− 7·01	189·35	+0·07	259·4
Sample B (2).							
+0·4	262·6	10·05	389·7	19·05	550·7	26·2	712·0
2·75	302·0	13·2	441·1	21·9	607·1	28·05	760·55
6·65	341·3	16·35	499·8	24·2	661·2		

Vapour-Pressures at High Temperatures.

The volumes of a gram of liquid and saturated vapour and the vapour-pressures at temperatures above the ordinary boiling-point were determined with the pressure apparatus employed in my previous researches. The tube containing the isopentane was heated by the vapour of pure liquids boiling under known pressures (Ramsay and Young, Trans. Chem. Soc. xlvii. p. 640; Young, ibid. lv. p. 483). The temperatures are those of an air-thermometer. The pressures, determined by means of air-gauges, are corrected for (1) the difference in height of the columns of mercury in the air-gauge and volume-tube; (2) the expansion of the heated column of mercury; (3) the pressure of the column of isopentane; (4) the deviation of air from Boyle's law, as determined by Amagat.

There were eight series of determinations, and, as a rule, four readings of pressure were taken at each temperature, the volume being altered as much as possible. The individual readings agreed very well together, and the mean values only are given in the following table (p. 613).

The constants for Biot's formula

$$\log p = a + b\alpha^t + c\beta^t$$

are given below.

$$a = 11{\cdot}371605;$$

$$b = -8{\cdot}030139, \quad \log b = 0{\cdot}9047231,$$

$$c = -1{\cdot}575796, \quad \log c = 0{\cdot}1975000;$$

$$\log \alpha = \bar{1}{\cdot}99968451,$$

$$\log \beta = \bar{1}{\cdot}99484097,$$

$$t = t^\circ\,\mathrm{C.} + 30.$$

The vapour-pressures calculated from Biot's formula are also given in the table.

Table of Vapour-Pressures.

Temperature.	Dynamical Method.	I. A.	II. B.	III. A.	IV. A.	V. B.	VI. A.	VII. A.	VIII. A.	Calculated.
−30	58·55	......	......	......	......	......	......	......	......	58·30
−20	100·0	......	......	......	......	......	......	......	......	100·06
−10	164·05	......	......	......	......	......	......	......	......	163·95
0	257·35	......	......	......	......	......	......	......	......	257·74
10	390·4	......	......	......	......	......	......	......	......	390·52
20	572·2	......	......	......	......	......	......	......	......	572·59
30	815·5	......	......	......	820	......	......	......	822	815·34
40	......	......	......	......	1137	......	......	......	1144	1131·1
50	......	......	1535	......	......	......	1536	1536	......	1533·2
60	......	......	2037	......	......	......	2036	......	......	2035·6
70	......	2657	2656	......	......	......	2657	......	......	2653·0
80	......	......	3385	3381	......	......	......	......	......	3400·8
90	......	4283	4281	4280	......	......	......	......	......	4295·6
100	......	......	5347	5344	......	......	......	......	......	5354·5
110	......	......	6583	6581	6586	6585	......	......	......	6596·1
120	......	......	8020	8020	8016	8016	......	......	......	8039·9
130	......	......	9685	9687	9682	9682	......	......	......	9706·7
140	......	11630	11640	11640	11630	11630	......	......	......	11620
150	......	13800	13800	13810	13800	......	......	......	......	13804
160	......	......	16320	16320	16320	......	......	......	......	16285
170	......	......	19110	19120	......	......	......	......	......	19094
176	......	......	......	20970	......	......	......	......	......	20950
180	......	......	22270	......	......	......	......	......	......	22262
183	......	......	......	23310	......	......	......	......	......	23288
185	......	......	24000	......	......	......	......	......	......	23992
186	......	......	......	24370	......	......	......	......	......	24350
187	......	......	24730	......	......	......	......	......	......	24713
187·4	......	......	......	24880	......	......	......	......	......	......
Critical 187·8	......	......	25010	25025	25020	......	......	......	......	25005

Volumes of a Gram of Liquid and Vapour.

In the first three series the mass of substance was determined by observing the volumes of liquid at a series of temperatures. These volumes were mapped against the temperatures and curves drawn through the points. The values at 0°, 13°·45, and 14°·4 were read off and were multiplied by the specific gravities at those temperatures.

For Series IV. and V. comparisons were made of the volumes of liquid and also of unsaturated vapour at a large number of different temperatures and pressures with those read from the curves constructed from the data obtained in the previous series.

The mass of substance in Series VI. was similarly ascertained by comparison of volumes with those read from the isothermals of Series IV. and V. at the same temperatures and pressures. So also with the remaining series, the calculated mass depended in each case on the data obtained in the preceding series.

A series of determinations of the volumes of unsaturated vapour was afterwards made by Thomas and myself in a modified Hofmann's apparatus, the mass of isopentane being determined by direct weighing. The smallest volumes of a gram in this series were nearly the same as the largest in Series VIII. with the pressure apparatus ; and as the isothermals constructed from the observations with the modified Hofmann's apparatus were quite continuous with those of Series VIII., the determination of mass in this series—which might be charged with the cumulative errors of each preceding determination—was shown to be accurate.

Orthobaric Volumes of a Gram of Liquid.

The volumes at 0°, 13°·45, and 14°·4 were calculated from the specific gravities at the same temperatures. The observations were made under atmospheric pressure, but the correction of the volumes to the true vapour-pressures has not been made, as the difference would be inappreciable.

In the pressure apparatus the volumes of liquid up to 130° were read directly, the vapour being completely condensed and the pressure made as nearly as possible equal to the vapour-pressure. At and above 140° the liquid is very compressible, and the volumes were therefore calculated from a series of readings of the volumes of vapour and of the total volume of liquid and saturated vapour at each temperature by the method described in the Trans. Chem. Soc. lxiii. p. 1200.

The volumes of liquid (when all vapour is condensed) and of saturated vapour (when all liquid is evaporated) may also be ascertained very simply by the following graphical method :—

Let the total volume (liquid and uncondensed vapour) at any reading $=$ V.
,, volume of saturated vapour at the same time $= v$.
,, ,, of liquid when all condensed $=$ A.
,, ,, of saturated vapour when all evaporated $=$ B.
,, ratio of the specific volume of saturated vapour to that of liquid $=$ R.
,, volume of liquid (*i.e.* $V - v) = A - n$.

Then the volume of vapour, $v = nR$,

and the total volume, $V = A - n + nR$,

or $V = A + n(R - 1)$.

Call $\dfrac{R-1}{R} = c$;

then
$$V = A + \frac{R-1}{R} . nR$$
$$= A + cv.$$

If we map the total volumes, (V_1, V_2, &c.) against the volumes of saturated vapour (v_1, v_2, &c.) and draw a straight line through the points, then when

$$v = 0, \quad V = A,$$

and when $v = V, \quad V = B.$

Again, let the volumes of saturated vapour v at any reading $= B - m$.

Also call the volume of liquid v' when the total volume $=$ V, so that $v' = \dfrac{m}{R}$.

Then the total volume, $V = B - m + \dfrac{m}{R}$

$$= B - m . \frac{R-1}{R}.$$

Make $$R-1=c',$$

then
$$V=B-(R-1)\cdot\frac{m}{R}$$
$$=B-c'v'.$$

If we map the total volumes V_1, V_2, &c., against the volumes of liquid v_1', v_2', &c., then when

$$v'=0,\quad V=B,$$

and when $$v'=V,\quad V=A.$$

The first method is better suited for the volumes of saturated vapour, the second for the volumes of liquid.

The orthobaric volumes of a gram of liquid, calculated from the experimental data, and also those read from the curves constructed from the observed values are given in the following table :—

Orthobaric Volumes of a Gram of Liquid.

Temp.	From Specific Gravities.	Series I.	Series II.	Series III.	Mean.	From Curves.
	c. c.	c. c.	c. c.	c. c.	c. c.	c. c.
0°	1·5644	......	......	......	1·5644	1·5644
10	......	1·5885	......	......	1·5885	1·5885
13·45	1·5971	......	......	......	1·5971	1·5972*
14·4	1·5996	......	......	......	1·5996	1·5996*
20	......	1·6140	......	......	1·6140	1·6141
30	......	1·6415	1·642	......	1·6415	1·6413
40	......	1·6700	1·670	......	1·6700	1·6700
50	......	1·7005	1·700	......	1·7005	1·7005
60	......	1·7330	1·734	......	1·7335	1·7329
70	......	1·7680	1·768	......	1·7680	1·7679
80	......	1·3045	1·806	......	1·8050	1·8055
90	......	1·8475	1·847	......	1·8475	1·8475
100	......	1·8945	1·894	......	1·8945	1·8940
110	......	1·9455	1·945	......	1·9455	1·9455
120	......	2·0040	2·003	......	2·0035	2·0037
130	......	2·0720	2·072	......	2·0720	2·0720
140	......	2·1525	2·156	2·153	2·1540	2·1530
150	......	2·2490	2·252	2·248	2·2495	2·2500
160	......	......	2·378	2·377	2·3775	2·3780
170	......	......	2·555	2·555	2·5550	2·5550
176	......	......	......	2·707	2·7070	2·7070
180	......	......	2·859	......	2·8590	2·8580
183	......	......	......	3·020	3·0200	3·0200
185	......	......	3·183	......	3·1830	3·1830
186	......	......	......	3·303	3·3030	3·3020
187	......	......	3·500	......	3·5000	3·5000
187·4	......	......	......	3·622	3·6220	3·6220
Critical 187·8	......	......	......	......	......	4·2660†

* From densities calculated from the formula

$$D_t=0·63923-0·0_3958\,t-0·0_5 13\,t^2.$$

† By the method of Cailletet and Mathias.

Orthobaric Volumes of a Gram of Vapour.

The volumes of saturated vapour were determined by three different methods :—

I. With the pressure apparatus from a series of four readings of the total volume of liquid and uncondensed vapour and of the vapour at each temperature at and above 110°.

This method (Trans. Chem. Soc. lxiii. p. 1200) gives very good results at high temperatures, but is not accurate when the ratio of the volume of a gram of saturated vapour to that of liquid is large. It has been described and recommended by Amagat (*Compt. Rend.* cxiv. p. 1093).

The graphical method described on p. 614 may be employed to ascertain the volume of saturated vapour when all the liquid is evaporated, and this, divided by the mass of substance in the tube, gives the volume of a gram of saturated vapour.

II. By heating a known quantity of liquid in a graduated sealed tube (Young, Trans. Chem. Soc. lix. p. 37 ; lxiii. p. 1201).

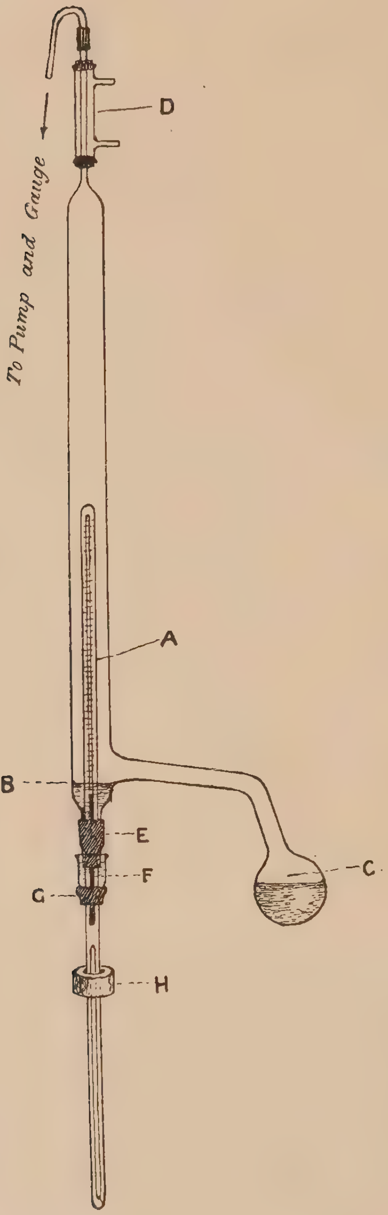
The method was originally devised for the purpose of determining the specific volumes (both as liquid and as saturated vapour) of liquids that attack mercury, but it has been found very convenient—in a modified and simpler form—for the determination of the volumes of a gram of the saturated vapours of ordinary substances whose specific volumes, as liquid, are known. The form of the sealed tube, the method of filling it, and the arrangements for heating it, are the same as are described in the paper referred to (vol. lix. pp. 40 and 41), but it is, of course, unnecessary to keep the lower part of the tube cool, and the water-jacket below is therefore not required.

The tube A is at first placed in the position shown in the diagram (fig. 1), with the level of the liquid in the tube below the condensed liquid B in the jacket. The liquid in the bulb C is then boiled—with the pressure rather lower than that corresponding to the lowest temperature required—and when the vapour has reached the condenser* D the sealed tube is slowly pushed up through the indiarubber tube E until the whole of the liquid in it is well above the surface of the condensed liquid B. The indiarubber tube should be kept under water for a day or two before being used, and should be surrounded by water until the sealed tube has been pushed up into its

---

* For liquids boiling above 160° a condenser is not required.

Fig. 1.



final position, otherwise considerable difficulty may be experienced in moving the sealed tube through it. The little glass tube F, filled with water and provided with a very short indiarubber tube G moving easily over the sealed tube, serves to keep the indiarubber tube E moist. The sealed tube is easily centred by means of a perforated cork H, held in position by a clamp and retort-stand. After the tube is in position the pressure under which the liquid in C is boiling is slowly raised until it corresponds to the required temperature, and a reading of the height of the liquid is then taken. A second reading is then taken after two or three minutes, and if the volume of liquid is smaller readings are taken from time to time until constancy is attained.

At moderate temperatures the volume of liquid should become constant almost immediately, but near the critical point the evaporation of the liquid becomes much slower, and this is especially the case if any appreciable amount of air or permanent gas is left in the tube. The amount of permanent gas must be exceedingly small, otherwise the results obtained are found to be inaccurate, owing probably to partial condensation of the vapour on the sides of the tube.

After the reading has become constant the pressure is again slowly raised—care being taken not to drive down the vapour below the top of the sealed tube—until the next temperature is reached.

If the top of the tube is cooled, condensation takes place in it, and there is danger of liquid remaining in contact with the walls of the tube, and of the apparent volume of liquid being therefore too small.

For the same reason it is advisable to begin treating the tube in the manner described, for if the tube were placed in its final position at the beginning of the experiment the liquid would boil and would collect at the top of the tube.

III. From the isothermals; the points of intersection of the curves representing the unsaturated vapour with the horizontal lines of vapour-pressure give the volumes of saturated vapour.

The logarithms of the volumes were mapped against the temperature, and the smoothed values read from the curve. These are given in the following table together with the values obtained by the three methods described above.

Orthobaric Volumes of a Gram of Vapour.

Temperature.	In Pressure Apparatus.				Sealed Tube Method.		From Isothermal Curves.	Mean.	From Curve.
	II.	III.	IV.	V.	I.	II.			
°	c. c.	c. c.	c. c.	c. c.	c. c.	c. c.	c c.	c. c.	c. c.
10·8	......	......	......	......	......	......	591·5*	591·5	
10	......	......	......	......	......	......	......	......	607·5
20	......	......	......	......	......	......	......	......	424·0
30	......	......	......	......	301	......	304·5	303	303·0
40	......	......	......	......	224	......	223·0	223·5	223·2
50	......	......	......	......	168·5	......	168·0	168·2	167·6
60	......	......	......	......	128·0	......	128·0	128·0	127·9
70	......	......	......	......	98·4	......	99·00	98·7	98·9
80	......	......	......	......	77·7	......	77·95	77·8	77·9
90	......	......	......	......	61·8	......	61·87	61·85	61·85
100	......	......	......	......	49·65	......	49·35	49·5	49·45
110	......	......	38·9	39·6	39·85	40·2	39·83	39·7	39·80
120	......	......	32·3	32·3	......	32·6	32·20	32·35	32·20
130	......	......	26·05	26·05	......	26·3	26·10	26·10	26·10
140	21·00	21·20	21·10	21·05	......	21·15	21·15	21·10	21·15
150	17·13	17·18	17·13	......	......	17·19	17·14	17·15	17·14
160	13·69	13·71	13·73	......	......	13·69	13·72	13·71	13·72
170	10·73	10·73	......	......	......	10·72	10·73	10·73	10·71
176	......	9·075	......	......	......	......	9·07	9·07	9·08
180	7·952	......	......	......	......	7·955	7·95	7·952	7·95
183	......	7·045	......	......	......	......	7·035	7·040	7·05
185	6·348	......	......	......	......	6·375	6·35	6·354	6·355
186	......	5·963	......	......	......	5·963	......	5·963	5·965
187	5·453	......	......	......	......	......	......	5·453	5·455
187·4	......	5·126	......	......	......	......	......	5·126	5·125
187·8 †	.....	......	......	......	......	......	......	4·266	4·266

* From determinations in the modified Hofmann's apparatus (Young and Thomas).

† By the method of Cailletet and Mathias.

Volumes of a Gram of Liquid and of Unsaturated Vapour.

Eight series of determinations were made in the pressure apparatus.

Series.	Specimen of Isopentane employed.	Mass of Isopentane. gram.	Data obtained.
I.	A	0·30244	Volumes of liquid up to 150°.
II.	A	0·09504	Volumes of liquid to critical point; a few volumes of unsaturated vapour at and above 176°; volumes above the critical point to 280°.
III.	B	0·11516	
IV.	A	0·03405	Volumes of unsaturated vapour from 140° to critical point; volumes above critical point to 280°.
V.	B	0·03010	
VI.	B	0·00888	Volumes of vapour at and above 90°.
VII.	B	0·003743	" " " 50°.
VIII.	B	0·001225	" " " 30°.

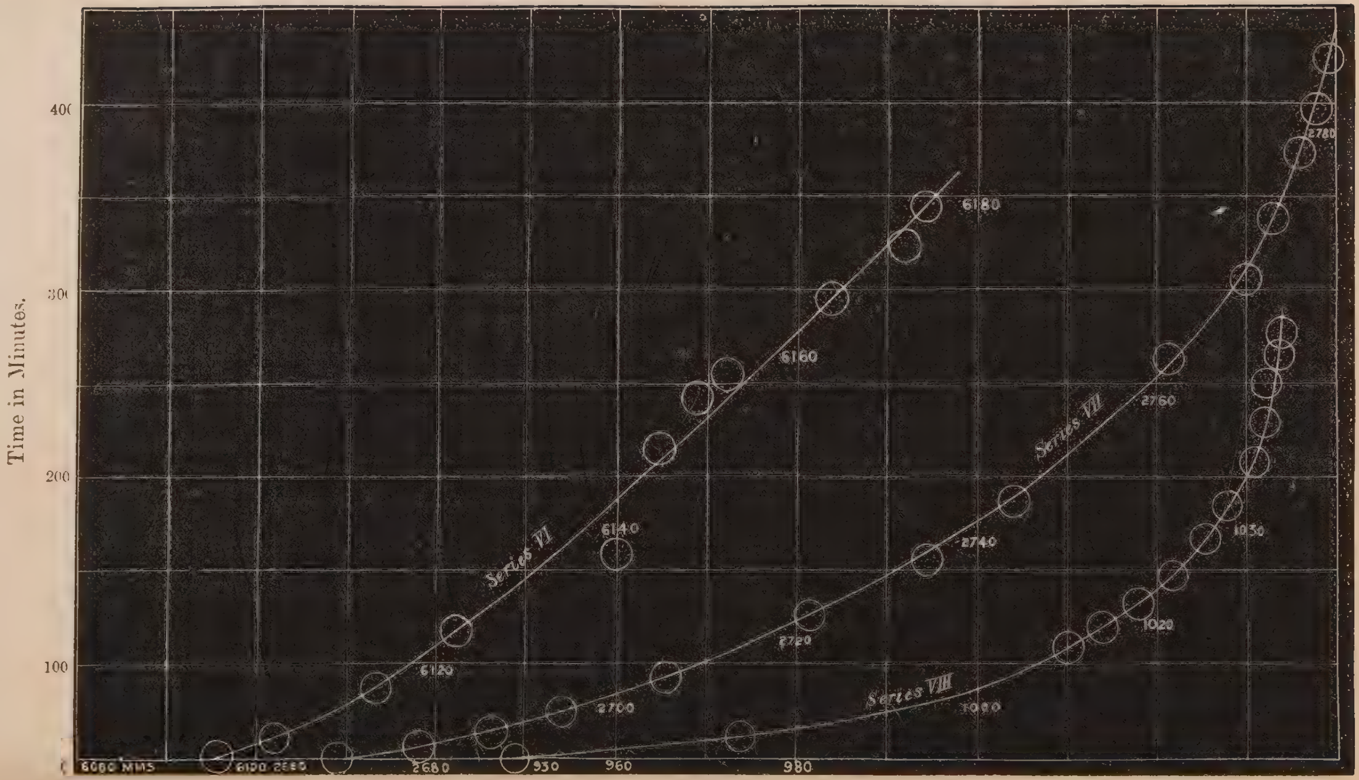
In Series VI. to VIII. the volumes were determined at temperatures up to 280°.

Correction of Pressures.—In addition to the corrections for the difference in height of the columns of mercury, the expansion of the heated column, and the deviation of air from Boyle's law, there is another which is of importance at the highest temperatures, but is somewhat difficult to estimate. This is the correction for the vapour-pressure of mercury.

It has been proved experimentally that the vapour of mercury penetrates a column of liquid over it with extreme slowness, and no correction has therefore been applied in the measurement of the vapour-pressure of isopentane or even of other substances with much higher critical temperatures.

When, however, there is only gas over the mercury the vapour of the metal diffuses slowly through it, the rate of diffusion increasing as the pressure of the gas is diminished. Even with the smallest quantity of isopentane at its largest volume, when the pressure of the gas was little over an atmosphere, the maximum pressure at 280° was not attained until after about four hours' heating. It is quite certain that with the larger quantities of substance a much longer time would be required, and as it was impossible, owing to other work, to keep the tube continuously heated for more than four or five hours, the only plan was to make an approximate estimate of the pressure exerted by the mercury-vapour.

Fig. 2.


Time in Minutes.
400
300
200
100
6080 MMS
6100 2660
2680
950
960
980
6120
6140
6160
6180
Series VI
2700
2720
2740
2760
2780
Series VII
1000
1020
1030
Series VIII

In the determinations of the volumes of a gram of unsaturated vapour the readings were always taken with diminishing volume, and at the higher temperatures the tube was heated for several hours with the substance at its largest volume. Readings were taken at short intervals, and were plotted against the time so as to get an idea of the rate of increase of the pressure.

The time-curves at 280° for the last three series are given in fig. 2. It will be seen that in Series VIII. the rise of pressure was at first very rapid, but that after two hours it had become very slow, and that the pressure after four hours was practically constant. The vapour-pressure of mercury at 280° is 158 millim., and the measured rise of pressure was 85 millim. The difference is, no doubt, due to the fact that the readings could not be begun until after the tube had been heated for some little time.

In Series VII. the rise was at first not quite so rapid as in Series VIII., and it was not until the tube had been heated for six hours that approximate constancy was attained. In this case the measured rise of pressure was 110 millim.

In Series VI. the rate of increase of pressure was much slower than in the later series, and the pressure was far from constant after five hours; the last reading was 78 millim. higher than the first.

It appears then that with the two smallest quantities of isopentane the mercury-vapour, after a sufficient time, exerted its full pressure, but that with the larger quantities the maximum pressure was not attained; also that when there is a column of liquid over the mercury no appreciable pressure is exerted by the vapour of the metal.

It was assumed that in Series II. and III. the vapour-pressure of the mercury amounted to one fourth of its maximum value; in Series IV. and V. to one half, in Series VI. to three quarters, and that in the last two series the full vapour-pressure was exerted*.

The time-curves for Series VII. and VIII. show that the error caused by assuming that the mercury-vapour exerted its full pressure cannot amount to more than one or two millim. in Series VIII., and to three or four millim. in Series VII.; and it is very unlikely that in the other series the error can amount to so much as a fourth of the maximum vapour-pressure of mercury. In Series VI., for instance, it is certain that the actual pressure exerted by the mercury-vapour was greater than half and less than the whole maximum pressure. At 280° the vapour-pressure of mercury is 158 millim., the rise of pressure actually measured 78 millim., and the pressure assumed to be exerted by the mercury vapour 118 millim. The error is therefore considerably less than 40 millim. At the largest volume the uncorrected pressure was 6174 millim., and the extreme error would therefore be under 0·7 per cent.

---

* In Series VII. the tube was heated for six hours at 250° and 280°, and for over four hours at 200° and 220°.

This is by far the worst case, for the vapour-pressure of mercury diminishes rapidly with fall of temperature, whilst with the larger quantities of isopentane the total pressure is proportionately increased. Thus, at 260° (Series VI.) the extreme error, calculated in the same way, would be 0·4 per cent., at 240° 0·25 per cent., at 200° 0·08 per cent., whilst at 280° (Series V.) it would be just over 0·2 per cent., and at 280° (Series III.) less than 0·1 per cent.

At temperatures above 150° the jacketing tube was protected from draughts and from loss of heat by radiation by an outer cylindrical glass tube about 8 or 10 millim. wider than the jacketing tube, the space at the top between the two tubes being closed by asbestos to prevent the upward current of air which would otherwise be formed. It was still possible that the tube containing the isopentane lost some heat by radiation and that its temperature was therefore a little too low.

In order to find whether this was the case the outer glass tube was covered with sheet asbestos after the eleventh reading at 280° in Series VIII. had been taken. It will be seen that the last two readings, with the tube doubly protected, fall accurately on the time-curve constructed from the previous readings.

Similar experiments had been made with the larger quantities of isopentane, but in no case was any alteration produced by covering the outer tube with asbestos. It may therefore be concluded that up to 280° the cylindrical glass tube affords sufficient protection from radiation.

The experimental results are given in the following Tables :—

Volumes of a Gram of Liquid and of Unsaturated Vapour.

SERIES I.

Temp.	Pressure. millim.	Volume. cub. cm.
10°......	790	1·5890
	4030	1·5870
	7960	1·5850
	11520	1·5840
	15140	1·5825
	20070	1·5810
	26310	1·5780
	32720	1·5755
	38350	1·5735
	43360	1·5715
	49970	1·5685
	54100	1·5675
15°·6 ...	810	1·6025
	4100	1·6015
	8110	1·5995
	11720	1·5975
	15420	1·5960
	20430	1·5945
	26760	1·5915
	33300	1·5885
	39040	1·5855
	44150	1·5835
	50880	1·5820
	55080	1·5795
30°......	820	1·6415
	4110	1·6385
	8110	1·6365
	11730	1·6345
	15410	1·6325
	20430	1·6300
	26770	1·6265
	33300	1·6235
	39020	1·6205
	44130	1·6185
	50860	1·6155
	55050	1·6135
40°......	1110	1·6700
	4110	1·6680
	8100	1·6660
	11710	1·6630
	15390	1·6610
	20400	1·6580
	26740	1·6535
	33250	1·6505
	38980	1·6470
	44070	1·6445
	50790	1·6415
	54990	1·6385
50°......	1530	1·7005
	5290	1·6975
	8080	1·6950
	11680	1·6925
	15360	1·6900
	20350	1·6870
	26670	1·6830
	33170	1·6785
	38870	1·6740
50°...... (*cont.*)	43960	1·6710
	50660	1·6675
	54840	1·6655
60°......	2040	1·7330
	5300	1·7305
	8090	1·7275
	11690	1·7245
	15370	1·7215
	20360	1·7180
	26680	1·7125
	33180	1·7080
	38870	1·7035
	43960	1·7000
	50650	1·6955
	54840	1·6920
70°......	2690	1·7680
	5300	1·7660
	8100	1·7620
	11700	1·7590
	15380	1·7550
	20380	1·7515
	26710	1·7450
	33210	1·7395
	38920	1·7345
	44020	1·7310
	50720	1·7260
	54910	1·7220
80°......	3390	1·8045
	5620	1·8020
	8090	1·7990
	11690	1·7955
	15360	1·7910
	20360	1·7855
	26880	1·7795
	33200	1·7730
	38910	1·7675
	44000	1·7625
	50700	1·7565
	54890	1·7525
90°......	4290	1·8475
	6000	1·8450
	8110	1·8420
	11710	1·8365
	15400	1·8315
	20400	1·8255
	26720	1·8170
	33230	1·8090
	38950	1·8025
	44040	1·7975
	50750	1·7910
	54940	1·7860
100° ...	5360	1·8945
	8130	1·8900
	11730	1·8830
	15410	1·8765
	20410	1·8690
	26740	1·8590
100° ... (*cont.*)	33240	1·8500
	38960	1·8420
	44050	1·8355
	50760	1·8270
	54950	1·8225
110° ...	6580	1·9455
	8460	1·9405
	11740	1·9335
	15420	1·9260
	20420	1·9170
	26750	1·9050
	33260	1·8945
	38990	1·8845
	44100	1·8765
	50800	1·8670
	54990	1·8610
120° ...	8020	2·0040
	10310	1·9970
	15400	1·9835
	20390	1·9705
	26700	1·9560
	33200	1·9420
	38900	1·9305
	43990	1·9215
	50700	1·9105
	54880	1·9035
130° ...	9670	2·0720
	11740	2·0640
	15420	2·0505
	20430	2·0330
	26750	2·0150
	33260	1·9975
	38970	1·9835
	44070	1·9710
	50770	1·9570
	54950	1·9485
140° ...	11640	2·1525
	13030	2·1450
	15360	2·1320
	20330	2·1100
	26610	2·0835
	33070	2·0615
	38740	2·0440
	43800	2·0290
	50460	2·0120
	54620	2·0015
150° ...	13800	2·2490
	15370	2·2365
	17740	2·2190
	20340	2·2010
	26620	2·1645
	33100	2·1335
	38780	2·1110
	43840	2·0920
	50520	2·0700
	54680	2·0580

SERIES II.

Temp.	Pressure. millim.	Volume. cub. cm.	Temp.	Pressure. millim.	Volume. cub. cm.	Temp.	Pressure. millim.	Volume. cub. cm.
30° ...	800	1·642	130° ... *(cont.)*	36770	1·989	187°·8 (Critical) *(cont.)*	29110	2·791
	7920	1·637		47250	1·966		31330	2·700
	15180	1·632	140° ...	11640	2·156		34600	2·608
	31400	1·624		15230	2·133		39480	2·517
	46780	1·617		25540	2·090		46740	2·426
40° ...	1160	1·670		36620	2·050	190° ...	25550	5·739
	7900	1·667		46920	2·021		25660	5·371
	15140	1·661	150° ...	13800	2·252		25760	4·999
	31350	1·652		17630	2·219		25860	4·628
	46710	1·643		25560	2·168		25880	4·258
50° ...	1535	1·700		36650	2·118		25930	3·892
	7930	1·695		46950	2·081		26170	3·523
	15200	1·690	160° ...	16320	2·378		26410	3·340
	31450	1·678		17380	2·360		26980	3·156
	46860	1·669		19950	2·329		28230	2·974
60° ...	2037	1·734		25200	2·279		29300	2·882
	7930	1·729		31100	2·237		30930	2·792
	15200	1·723		36130	2·205		33300	2·700
	31450	1·710		40560	2·182		36820	2·608
	46870	1·698		46270	2·156		41900	2·518
70° ...	2656	1·768	170° ...	19110	2·555		49310	2·426
	7930	1·762		20580	2·512	195° ...	27010	5·740
	15190	1·754		25200	2·425		27220	5·372
	31430	1·742		31100	2·354		27430	5·000
	46830	1·728		36130	2·307		27630	4·629
80° ...	3385	1·806		40540	2·275		27840	4·259
	8010	1·799		46270	2·238		28100	3·892
	15340	1·791	180° ...	22270	2·859		28610	3·523
	31720	1·774		23440	2·756		29130	3·340
	47250	1·759		27260	2·602		30090	3·157
90° ...	4280	1·847		31100	2·517		31790	2·974
	8000	1·842		36130	2·430		33150	2·883
	15310	1·832		40550	2·388		35110	2·792
	31680	1·811		46260	2·338		37900	2·700
	47220	1·793	185° ...	24000	3·183		41810	2·609
100° ...	5350	1·894		24260	3·082		47470	2·518
	7990	1·888		25170	2·928	200° ...	28410	5·741
	15300	1·875		27220	2·773		28720	5·372
	31660	1·853		29640	2·673		29070	5·001
	47170	1·833		32530	2·594		29420	4·630
110° ...	6583	1·945		36060	2·522		29790	4·260
	8000	1·943		40470	2·458		30340	3·893
	15300	1·927		46170	2·395		31180	3·524
	31660	1·897	187°·8 (Critical)	24900	5·739		31970	3·340
	47180	1·872		24960	5·371		33240	3·157
120° ...	8020	2·003		24990	4·999		35450	2·975
	10190	1·999		25000	4·628		37070	2·883
	20340	1·970		25010	4·258		39380	2·792
	31690	1·946		25020	3·892		42490	2·701
	47200	1·916		25070	3·523		46880	2·609
130° ...	9685	2·072		25190	3·339	210° ...	31170	5·742
	15340	2·048		25650	3·156		31740	5·374
	25710	2·019		26670	2·974		32350	5·002

Series II. (*continued*).

Temp.	Pressure. millim.	Volume. cub. cm.	Temp.	Pressure. millim.	Volume. cub. cm.	Temp.	Pressure. millim.	Volume. cub. cm.
210° ...	33020	4·631	220° ...	44830	3·250	240° ...	47280	4·080
(*cont.*)	33790	4·261	(*cont.*)	46250	3·159	(*cont.*)	48020	3·989
	34830	3·894		48060	3·067		48800	3·897
	35500	3·710	230° ...	35620	5·745	250° ...	42020	5·748
	36420	3·525		37700	5·377		43600	5·379
	37730	3·341		38860	5·004		45420	5·007
	39640	3·158		40160	4·633		46480	4·821
	41000	3·066		41780	4·263		47510	4·635
	42710	2·975		42800	4·079		48150	4·543
	44980	2·884		43970	3·896		48760	4·450
	48020	2·793		45460	3 712	260° ...	44670	5·749
220° ...	33910	5·744		46230	3·619		45570	5·565
	34700	5·375		47290	3·526		46490	5·381
	35570	5·003		48420	3·435		47550	5·194
	36540	4·632	240° ...	39350	5·747		48080	5·102
	37790	4·262		40620	5·378		48650	5·008
	38540	4·078		42140	5·006	270° ...	47380	5·751
	39410	3·895		43840	4·634		47880	5·659
	40440	3·711		44870	4·449		48400	5·566
	41750	3·525		45980	4·264		48830	5·475
	43620	3·342						

SERIES III.

Temp.	Pressure. millim.	Volume. cub. cm.	Temp.	Pressure. millim.	Volume. cub. cm.	Temp.	Pressure. millim.	Volume cub. cm.
160° ...	16320	2·377	176° ...	27130	2·508	186° ...	23900	7·177
	16420	2·375	(*cont.*)	29550	2·467		24030	6·954
	18220	2·350		32450	2·426		24130	6·731
	20440	2·325		35970	2·383		24230	6·507
	23290	2·296		40370	2·340		24290	6·282
	27110	2·264		46070	2·298		24360	6 057
	32420	2·227		49610	2·273		24370	5 963
	38010	2·193		53710	2·249		,,	3·303
	43000	2 170	183° ...	23160	7·397		25110	3·030
	49570	2·140		23210	7·286		26080	2·902
	53680	2·126		23260	7·176		27150	2·822
170° ...	19120	2·555		23300	7·064		28300	2·757
	19290	2·545		23310	7·045		29560	2·704
	20470	2·513		,,	3·020	187°·4	24350	6·954
	23320	2·455		23320	3·008		24570	6·508
	27120	2·399		24160	2·883		24740	6 057
	32430	2·339		25080	2·805		24800	5·832
	38020	2·292		27120	2·698		24840	5·608
	43010	2·258		29530	2·619		24870	5·384
	49580	2·218		32430	2·550		24880	5·126
	53680	2·199		35950	2·490		,,	3·622
176° ...	20970	2·707		40350	2·429		24890	3·603
	21810	2·660		46040	2·372		24910	3·492
	23320	2·602		49570	2·343		24990	3·382
	25090	2·551		53680	2·314		25120	3·281

Series III. (*continued*).

Temp.	Pressure. millim.	Volume. cub. cm.	Temp.	Pressure. millim.	Volume. cub. cm.	Temp.	Pressure. millim.	Volume. cub. cm.
187°·4	25256	3·205	190° ...	25180	6·508	205° ..	29960	5·610
(*cont.*)	26079	3·016	(*cont.*)	25400	6·058	(*cont.*)	30530	5·162
	26241	2·992		25590	5·608		31090	4·718
	27153	2·900		25710	5·160		31780	4·271
	27313	2·883		25780	4·716		32740	3·826
	28302	2·818		25850	4·269		33490	3·605
	28472	2·807		25950	3·824		34560	3·384
187°·75	24430	6·954		26040	3·603		36370	3·162
(Critical)	24550	6·731		26300	3·382		37760	3·052
	24640	6·508		26940	3·160		39660	2·941
	24750	6·282		28560	2·939		42360	2·831
	24820	6·057		30170	2·829		46260	2·720
	24880	5·832		32780	2·718		52090	2·610
	24940	5·608		36810	2·608	210° ...	29350	6·958
	24970	5·384		43080	2·497		30000	6·511
	25000	5·160		53320	2·387		30660	6·061
	25010	4·938	195° ...	26050	6·955		31340	5·611
	25020	4·716		26410	6·509		32030	5·163
	25030	4·268		26740	6·059		32840	4·718
	25030	3·824		27050	5·609		33730	4·271
187°·8	25040	3·603		27320	5·161		35040	3·826
(Critical)	25110	3·382		27560	4·717		36010	3·605
	25610	3·160		27810	4·270		37410	3·384
	26140	3·050		28150	3·825		39580	3·162
	26970	2·939		28450	3·604		41210	3·052
	28430	2·829		28980	3·383		43500	2·941
	30790	2·718		30000	3·161		46580	2·831
	34570	2·608		30880	3·051		51040	2·720
	40670	2·497		32220	2·940		53910	2·660
	46050	2·431		34200	2·830	220° ...	31480	6·959
	49580	2·394		37150	2·719		32330	6·513
	53680	2·361		41770	2·609		33260	6·062
188°·0	24910	6·057		48930	2·498		34170	5·612
	25010	5·608		53150	2·449		35180	5·164
	25070	5·160	200° ...	27180	6·956		36330	4·719
	25090	4·716		27630	6·510		37730	4·272
	25100	4·492		28080	6·059		39720	3·827
	25100	4·268		28520	5·609		41080	3·606
	25110	4·046		28890	5·161		43100	3·385
	25130	3·824		29310	4·717		44460	3·274
	25160	3·603		29750	4·270		46150	3·163
	25300	3·382		30410	3·825		48450	3·053
188°·3	24940	6·057		30930	3·604		51170	2·942
	25070	5·608		31740	3·383		53960	2·857
	25140	5·160		33150	3·161	230° ...	33610	6·961
	25170	4·938		34310	3·051		34650	6·515
	25180	4·716		35910	2·940		35750	6·064
	25190	4·492		38220	2·830		36940	5·614
	25190	4·268		41710	2·719		38260	5·165
	25210	4·046		46900	2·609		39800	4·720
	25220	3·824		53160	2·516		41750	4·273
	25250	3·603	205° ...	28290	6·957		44440	3·828
	25400	3·382		28820	6·510		46360	3·607
190° ...	24920	6·954		29390	6·060		47640	3·496

Series III. (*continued*).

Temp.	Pressure. millim.	Volume. cub. cm.	Temp.	Pressure. millim.	Volume. cub. cm.	Temp.	Pressure. millim.	Volume. cub. cm.
230° ...	49010	3·386	250° ...	42550	5·616	270° ...	41870	6·968
(*cont.*)	50780	3·275	(*cont.*)	44510	5·168		43670	6·522
	52880	3·164		46890	4·723		45690	6·069
240° ...	35700	6·963		48350	4·500		48030	5·619
	36950	6·516		49910	4·275		49320	5·395
	38310	6·065		51900	4·053		50700	5·170
	39750	5·615		53000	3·940		52230	4·948
	41440	5·167	260° ...	39850	6·967		53070	4·837
	43360	4·721		41440	6·520	280° ...	43890	6·970
	45930	4·274		43240	6·068		45940	6·523
	47490	4·052		45280	5·618		48240	6·071
	49370	3·829		47590	5·169		49410	5·846
	51780	3·608		48920	4·947		50770	5·621
	53320	3·497		50430	4·724		52170	5·396
250° ...	37820	6·965		52170	4·501		52980	5·284
	39210	6·518		53080	4·388		53760	5·172
	40760	6·066						

SERIES IV.

Temp.	Pressure. millim.	Volume. cub. cm.	Temp.	Pressure. millim.	Volume. cub. cm.	Temp.	Pressure. millim.	Volume. cub. cm.
150° ...	12870	19·39	176° ...	18230	13·15	183° ...	23030	7·585
	13120	18·77	(*cont.*)	19090	11·91	(*cont.*)	23180	7·280
	13370	18·15		19950	10·67		23260	7·095
	13600	17·52		20360	10·05	185° ...	15020	19·41
160° ...	13520	19·40		20750	9·435		15720	18·16
	14080	18·15		20920	9·130		16480	16·91
	14670	16·89	180° ...	14730	19·41		17300	15·65
	14980	16·27		15400	18·16		18190	14·40
	15290	15·64		16130	16·90		19130	13·16
	15610	15·02		16910	15·65		20110	11·91
	15940	14·39		17750	14·40		21130	10·67
	16260	13·77		18620	13·15		22150	9·440
170° ...	14130	19·40		19540	11·91		23070	8·205
	14740	18·15		20470	10·67		23460	7·585
	15380	16·89		21360	9·440		23780	6·970
	16110	15·64		21770	8·820		23910	6·665
	16850	14·39		22130	8·200		24000	6·355
	17240	13·77		22260	7·955	186° ...	21260	10·67
	17620	13·16	183° ...	14900	19·41		22290	9·440
	18020	12·53		15590	18·16		23270	8·205
	18400	11·91		16330	16·90		23670	7·585
	18770	11·29		17140	15·65		24010	6·970
	18940	10·98		18000	14·40		24150	6·665
176° ...	14480	19·41		18920	13·16		24270	6·355
	15130	18·15		19880	11·91		24350	6·045
	15840	16·90		20870	10·67	187°·85	15190	19·41
	16600	15·64		21820	9 440	(Critical)	15900	18·17
	17380	14·39		22680	8·205		16680	16·91

Series IV. (*continued*).

Temp.	Pressure. millim.	Volume. cub. cm.	Temp.	Pressure. millim.	Volume. cub. cm.	Temp.	Pressure. millim.	Volume. cub. cm.
187°·85 (Critical) (*cont.*)	17510	15·65	210° ... (*cont.*)	17310	18·17	250° ...	18760	19·44
	18430	14·40		18220	16·92		19780	18·19
	19390	13·16		19220	15·66		20920	16·94
	20400	11·91		20300	14·41		22170	15·68
	21480	10·67		21500	13·17		23600	14·43
	22560	9·440		22820	11·92		25190	13·18
	23570	8·205		24280	10·68		27010	11·93
	24430	6·970		25840	9·445		29130	10·69
	24910	5·740		27520	8·210		31520	9·455
	25000	5·125		29300	6·975		34340	8·220
	25020	4·505		31150	5·740		37740	6·980
	25030	3·890		33260	4·505		42030	5·750
190° ...	15310	19·41	220° ...	17060	19·43		44630	5·130
	16040	18·17		17930	18·18	260° ...	19320	19·45
	16840	16·91		18900	16·93		20360	18·20
	17690	15·65		19960	15·66		21570	16·94
	18600	14·40		21150	14·41		22910	15·68
	19590	13·16		22430	13·17		24410	14·43
	20640	11·91		23870	11·92		26100	13·18
	21750	10·67		25500	10·68		28050	11·94
	22880	9·440		27270	9·450		30300	10·70
	23940	8·205		29250	8·210		32920	9·460
	24900	6·970		31440	6·975		36050	8·220
	25540	5·740		33860	5·745		39780	6·980
	25820	4·505		36930	4·510		44640	5·750
195° ...	15610	19·42	230° ...	17630	19·43		47840	5·135
	16370	18·16		18540	18·18	270° ...	19880	19·45
	17180	16·91		19560	16·93		20980	18·20
	18070	15·65		20690	15·67		22230	16·95
	19030	14·40		21940	14·42		23610	15·69
	20080	13·16		23350	13·17		24200	14·44
	21200	11·91		24930	11·93		27000	13·19
	22400	10·67		26690	10·69		29080	11·94
	23630	9·440		28690	9·450		31460	10·70
	24880	8·205		30940	8·215		34280	9·460
	26020	6·970		33550	6·975		37690	8·225
	26980	5·740		36570	5·745		41820	6·985
	27650	4·505		40630	4·510		47390	5·755
200° ...	15910	19·42	240° ...	18210	19·44		50900	5·135
	16680	18·17		19170	18·19	280° ...	20410	19·46
	17530	16·92		20250	16·94		21570	18·21
	18450	15·65		21450	15·67		22870	16·95
	19470	14·41		22780	14·42		24340	15·69
	20560	13·16		24300	13·18		26000	14·44
	21740	11·92		25980	11·93		27890	13·19
	23030	10·68		27960	10·69		30070	11·94
	24380	9·445		30120	9·455		32600	10·70
	25790	8·205		32690	8·215		35630	9·465
	27140	6·970		35700	6·980		39280	8·225
	28390	5·740		39310	5·745		43810	6·985
	29500	4·505		41540	5·130		49930	5·755
210° ...	16490	19·42						

Series V.

Temp.	Pressure. millim	Volume. cub. cm.	Temp.	Pressure. millim.	Volume. cub. cm.	Temp.	Pressure. millim.	Volume. cub. cm.
140° …	11160	22·63	180° … (*cont*)	19940	11·37	240° … (*cont.*)	23850	13·49
	11375	21·93		20470	10·67		25750	12·09
	11490	21·58		20970	9·980		27890	10·69
	11595	21·22		21470	9·280		30390	9·290
150° …	11920	21·93		21900	8·580		31820	8·590
	12170	21·23		22100	8·235		33370	7·895
	12430	20·52	200° …	14510	21·96		35090	7·200
	12700	19·81		15640	19·84		36940	6·500
	12970	19·10		16970	17·71		39100	5·805
	13260	18·39		18500	15·59		41680	5·105
	13550	17·69		20260	13·48		45050	4·410
	13700	17·30		21570	12·08	260° …	17440	21·99
160°…	12470	21·94		23010	10·68		18960	19·87
	13030	20·53		24550	9·280		20780	17·74
	13600	19·11		25310	8·585		22960	15·62
	14290	17·69		26100	7·890		25610	13·50
	14620	16·98		26890	7·190		27750	12·10
	14970	16·28		27620	6·495		30260	10·70
	15330	15·58		28320	5·800		33240	9·295
	15680	14·88		28970	5·100		34950	8·595
	16050	14·17		29590	4·405		36850	7·900
170° …	12990	21·94	220° …	15500	21·97		39020	7·205
	13600	20·53		16760	19·85		41400	6·505
	14260	19·11		18250	17·72		44270	5·805
	14960	17·70		19990	15·60		47940	5·110
	15740	16·28		22080	13·49		52780	4·410
	16560	14·88		23660	12·08	280° …	18390	22·01
	17410	13·47		25450	10·69		20030	19·88
	17850	12·77		27480	9·285		22000	17·75
	18290	12·07		28580	8·590		24390	15·63
	18710	11·37		29770	7·890		27350	13·51
	18930	11·02		31010	7·195		29740	12·11
180° …	13500	21·95		32320	6·500		32600	10·71
	14150	20·54		33710	5·800		36030	9·300
	14860	19·12		35310	5·100		38060	8·600
	15640	17·70		37240	4·405		40260	7·905
	16490	16·29	240° …	16470	21·98		42890	7·210
	17400	14·88		17870	19·86		45920	6·510
	18390	13·47		19530	17·73		49530	5·810
	19420	12·07		21480	15·61			

Series VI.

Temp.	Pressure. millim.	Volume. cub. cm.	Temp.	Pressure. millim.	Volume. cub. cm.	Temp.	Pressure. millim.	Volume. cub. cm.
90° ...	3585	76·62	140° ...	9411	29·06	180° ...	12500	24·37
	3678	74·24	*(cont.)*	9993	26·69	*(cont.)*	13480	22·01
	3786	71·86		10640	24·34		14580	19·64
	3895	69·47		11360	21·98		15890	17·28
	4012	67·07	150° ...	4463	74·35		17380	14·91
	4135	64·67		4887	67·17		19070	12·56
	4263	62·26		5400	59·96	200° ...	5084	74·45
100° ...	3813	74·26		6037	52·79		5577	67·26
	4040	69·49		6830	45·63		6186	60·04
	4297	64·68		7498	40·89		6943	52·86
	4432	62·28		8267	36·17		7893	45·70
	4585	59·88		9198	31·43		8697	40·94
	4739	57·49		10410	26·70		9672	36·21
	4910	55·10		11110	24·34		10890	31·47
	5081	52·73		11900	21·98		12430	26·74
	5271	50·35		12770	19·63		13370	24·38
110° ...	3946	74·27		13740	17·26		14460	22·02
	4182	69·51	160° ...	4589	74·37		15740	19·65
	4447	64·70		5032	67·19		17250	17·29
	4749	59·90		5564	59·98		19010	14·92
	5091	55·11		6224	52·81	220° ...	5317	74·48
	5482	50·37		7056	45·64		5847	67·30
	5933	45·59		7734	40·90		6491	60·07
	6185	43·22		8564	36·18		7294	52·89
	6472	40·85		9573	31·44		8314	45·72
120° ...	4079	74·29		10840	26·71		9182	40·96
	4458	67·12		12430	21·99		10220	36·23
	4918	59·91		13400	19·63		11530	31·49
	5472	52·75		14480	17·26		13210	26·75
	6167	45·60		15660	14·90		14250	24·39
	6717	40·86	170° ...	4713	74·39		15450	22·03
	7040	38·50		5172	67·21		16880	19·66
	7376	36·14		5724	59·99		18580	17·30
	7754	33·76		6403	52·82		20620	14·93
	7958	32·59		7272	45·66	240° ...	5562	74·52
130° ...	4206	74·31		7979	40·91		6119	67·34
	4603	67·14		8844	36·19		6807	60·10
	5079	59·93		9910	31·45		7657	52·92
	5665	52·76		11250	26·71		8740	45·74
	6396	45·61		12050	24·36		9658	40·98
	6985	40·87		12960	22·00		10780	36·25
	7689	36·15		14010	19·64		12180	31·50
	8083	33·77		15200	17·27		14010	26·76
	8527	31·41		16540	14·90		15120	24·40
	9012	29·05		18000	12·55		16440	22·04
	9553	26·69	180° ...	4834	74·41		18010	19·67
140° ...	4337	74·33		5302	67·22		19910	17·30
	4751	67·16		5876	60·01		22230	14·94
	5242	59·95		6583	52·83	260° ...	5805	74·56
	5856	52·78		7484	45·67		6389	67·37
	6617	45·62		8222	40·92		7125	60·13
	7243	40·88		9122	36·20		8022	52·94
	7977	36·16		10240	31·46		9160	45·76
	8884	31·42		11650	26·72		10140	41·00

Series VI. (*continued*).

Temp.	Pressure. millim.	Volume. cub. cm.	Temp.	Pressure. millim	Volume. cub. cm.	Temp.	Pressure. millim.	Volume. cub. cm.
260° ...	11330	36·26	280° ...	6675	67·40	280° ...	18410	22·06
(*cont.*)	12830	31·52	(*cont.*)	7453	60·16	(*cont.*)	20250	19·69
	14780	26·77		8380	52·97		22520	17·32
	16000	24·41		9608	45·79		25330	14·95
	17430	22·05		10660	41·03		27040	13·76
	19130	19·68		11900	36·28		28980	12·59
	21220	17·31		13490	31·53		31240	11·40
	23760	14·94		15580	26·79		34870	10·21
280° ...	6065	74·60		16870	24·43		37030	9·02

SERIES VII.

Temp.	Pressure. millim.	Volume. cub. cm.	Temp.	Pressure. millim.	Volume. cub. cm.	Temp.	Pressure. millim.	Volume. cub. cm.
50° ...	1427	181·60	90° ...	2054	142·05	120° ...	3590	85·72
	1471	175·95	(*cont.*)	2311	125·05	(*cont.*)	4065	74·50
	1514	170·30		2639	108·10		4687	63·30
60° ...	1479	181·65		2913	96·86		5530	52·13
	1524	176·00		3252	85·66	130° ...	1886	176·30
	1570	170·35		3448	80·04		2076	159·25
	1620	164·70		3669	74·44		2313	142·20
	1676	159·00		3923	68·85		2608	125·20
	1732	153·30		4209	63·25		2984	108·20
	1793	147·60	100° ...	1732	176·15		3303	96·96
	1858	141·90		1906	159·15		3698	85·75
	1927	136·25		2120	142·10		4193	74·52
	2001	130·60		2388	125·10		4841	63·32
70° ...	1575	176·05		2727	108·15		5717	52·14
	1679	164·70		3012	96·88	140° ...	1936	176·35
	1793	153·30		3360	85·68		2133	159·30
	1924	141·90		3803	74·46		2377	142·25
	2077	130·60		4368	63·27		2681	125·25
	2253	119·35		5126	52·10		3071	108·25
	2354	113·70	110° ...	1784	176·20		3401	96·98
	2462	108·05		1963	159·20		3808	85·78
	2583	102·45		2185	142·10		4326	74·54
80° ...	1627	176·10		2461	125·10		5000	63·34
	1731	164·75		2816	108·15		5914	52·16
	1851	153·35		3113	96·91	160° ...	2035	176·45
	1986	141·95		3474	85·70		2242	159·40
	2146	130·65		3943	74·48		2503	142·35
	2332	119·40		4534	63·29		2824	125·35
	2552	108·05		5328	52·11		3238	108·30
	2813	96·83	120° ...	1837	176·25		3591	97·03
	2965	91·24		2020	159·20		4023	85·82
	3134	85·64		2251	142·15		4577	74·58
	3321	79·99		2537	125·15		5296	63·37
90° ...	1681	176·10		2902	108·20		6292	52·18
	1848	159·10		3209	96·93			

Series VII. (*continued*).

Temp.	Pressure. millim.	Volume. cub. cm.	Temp.	Pressure. millim.	Volume. cub. cm.	Temp.	Pressure. millim.	Volume. cub. cm.
180° ...	2132	176·55	200° ..	5888	63·43	250° ...	4979	86·01
	2353	159·50	(*cont.*)	7025	52·23	(*cont.*)	5679	74·76
	2625	142·35	220° ...	2330	176·75		6620	63·51
	2966	125·35		2575	159·70		7211	57·92
	3405	108·35		2877	142·50		7910	52·30
	3775	97·08		3253	125·50		8781	46·68
	4239	85·86		3738	108·45		9871	41·06
	4822	74·62		4156	97·18		11275	35·44
	5590	63·40		4666	85·95	280° ...	2622	177·00
	6654	52·20		5318	74·70		2912	159·90
200° ...	2231	176·65		6176	63·46		3252	142·75
	2463	159·60		7381	52·26		3680	125·70
	2751	142·45	250° ...	2477	176·90		4234	108·65
	3108	125·45		2741	159·80		4712	97·33
	3571	108·40		3068	142·60		5303	86·08
	3962	97·13		3469	125·60		6043	74·81
	4452	85·90		3984	108·55		7065	63·56
	5066	74·66		4431	97·26		8459	52·34

SERIES VIII.

Temp.	Pressure. millim.	Volume. cub. cm.	Temp.	Pressure. millim.	Volume. cub. cm.	Temp.	Pressure. millim.	Volume. cub. cm.
30° ...	776	321·2	60° ..	1857	141·9	90° ...	1152	261·7
	797	312·6	(*cont.*)	1964	133·4	(*cont.*)	1317	227·4
	816	304·0	70° ...	825	347·4		1418	210·3
40° ...	786	329·9		866	330·2		1537	193·2
	827	312·7		965	295·7		1678	176·2
	873	295·5		1085	261·6		1846	159·1
	924	278·5		1239	227·3		2054	142·0
	980	261·4		1334	210·2		2314	124·9
	1044	244·2		1444	193·1	100° ...	822	382·2
	1117	227·1		1574	176·1		860	365·0
50° ...	814	330·0		1732	159·0		947	330·4
	903	295·6		1922	142·0		1054	296·0
	1015	261·4		2164	124·9		1186	261·8
	1082	244·3	80° ...	812	364·8		1357	227·5
	1158	227·2		893	330·2		1462	210·4
	1246	210·1		993	295·8		1584	193·2
	1348	193·0		1118	261·7		1732	176·3
	1468	176·0		1277	227·4		1904	159·2
60° ..	799	347·4		1377	210·3		2120	142·1
	839	330·1		1492	193·2		2389	124·9
	933	295·7		1627	176·2	120° ...	832	399·6
	1049	261·5		1789	159·1		909	365·2
	1199	227·3		1988	142·0		1002	330·5
	1290	210·2		2236	124·9		1113	296·1
	1397	193·1	90° ...	835	364·9		1254	261·9
	1524	176·1		920	330·3		1435	227·6
	1673	159·0		1024	295·9		1547	210·5

Series VIII. (*continued*).

Temp.	Pressure. millim.	Volume. cub. cm.	Temp.	Pressure. millim.	Volume. cub. cm.	Temp.	Pressure. millim.	Volume. cub. cm.
120° ... (*cont.*)	1678	193·4	180° ...	853	452·3	220° ... (*cont.*)	1820	228·2
	1834	176·4		963	400·2		1963	211·0
	2020	159·3		1051	365·7		2130	193·9
	2248	142·1		1159	331·1		2332	176·8
	2536	125·0		1290	296·6		2573	159·7
140° ...	838	417·1		1455	262·4	250° ...	854	523·0
	956	365·4		1677	228·0		915	488·2
	1053	330·7		1800	210·8		1025	435·8
	1172	296·3		1951	193·7		1161	383·6
	1321	262·1		2135	176·7		1340	331·6
	1513	227·7		2358	159·5		1495	297·2
	1632	210·6		2625	142·3		1686	262·8
	1770	193·5		2970	125·2		1934	228·3
	1933	176·5	200° ...	857	470·1		2088	211·2
	2133	159·3		964	417·8		2269	194·0
	2377	142·2		1098	366·0		2480	177·0
	2684	125·1		1209	331·2		2740	159·8
160° ...	847	434·7		1349	296·8	280° ...	876	540·8
	958	382·8		1521	262·5		970	488·5
	1107	330·9		1744	228·1		1084	436·1
	1233	296·4		1880	211·0		1230	384·0
	1388	262·2		2041	193·8		1420	331·9
	1591	227·8		2233	176·7		1583	297·4
	1716	210·7		2466	159·6		1786	263·0
	1861	193·6	220° ...	861	487·8		2049	228·5
	2036	176·6		966	435·4		2213	211·4
	2247	159·4		1093	383·4		2402	194·2
	2503	142·3		1261	331·4		2631	177·1
	2825	125·2		1407	297·0		2907	159·9
				1587	262·6			

The Critical Volume and Density.

It is impossible to determine the critical volume accurately by direct experiment, but it may be calculated from the critical density, which may be ascertained with great accuracy by the method of Cailletet and Mathias (*Compt. Rend.* cii. p. 1202, civ. p. 1563; Mathias, *ibid.* cxv. p. 35).

In the following table the densities (mass of 1 cub. centim.) of liquid and saturated vapour and the mean densities are given at a series of temperatures, together with the mean densities calculated from the formula

$$D=0·3197-0·000454\,t.$$

The close agreement between the calculated and observed mean densities over such a wide range of temperature in this, as in so many other cases, justifies the very small extrapolation to the critical temperature. The mean density at this temperature, 187°·8, calculated from the formula, is 0·2344, and this is the critical density, for, at the critical temperature, the difference between the liquid and saturated vapour ceases to exist. The critical volume of a gram, calculated from the density, is 4·266 cub. centim.

Mean Densities of Liquid and Saturated Vapour.

Temperature.	Density.				
	Liquid.	Saturated Vapour.	Mean.	Calculated.	Δ × 10,000.
10°	·6295	·0016	·3156	·3152	−4
20	·6196	·0024	·3110	·3106	−4
30	·6092	·0033	·3062	·3061	−1
40	·5988	·0045	·3017	·3015	−2
50	·5881	·0060	·2970	·2970	0
60	·5769	·0078	·2924	·2924	0
70	·5656	·0101	·2878	·2879	+1
80	·5540	·0128	·2834	·2834	0
90	·5413	·0162	·2787	·2788	+1
100	·5278	·0203	·2741	·2743	+2
110	·5140	·0251	·2695	·2697	+2
120	·4991	·0311	·2651	·2652	+1
130	·4826	·0383	·2605	·2607	+2
140	·4642	·0473	·2557	·2561	+4
150	·4445	·0583	·2514	·2516	+2
160	·4206	·0729	·2468	·2470	+2
170	·3914	·0932	·2423	·2425	+2
176	·3694	·1103	·2398	·2398	0
180	·3498	·1258	·2378	·2380	+2
183	·3311	·1422	·2366	·2366	0
185	·3142	·1575	·2358	·2357	−1
186	·3028	·1677	·2353	·2352	−1
187	·2857	·1834	·2346	·2348	+2
187·4	·2761	·1951	·2356	·2346	−10
(Critical) 187°·8	......	......	......	·2344	

Critical Volume of a gram.........	4·266 cub. cm.
Critical Molecular Volume.........	306·5 cub. cm.

THEORETICAL CONCLUSIONS.

Relation of Pressure to Temperature at Constant Volume. Isochors.

For the larger volumes of a gram the pressures corresponding to definite volumes were read from the isothermals constructed from the data already given. This method was, however, not practicable in the case of the smaller volumes. Isobars were therefore first constructed, and the temperatures at definite volumes were then read from the isobars. The data from which the isobars were constructed are given in the table below, p. 638.

In the tables which follow (pp. 639–643) the data for two sets of isochors are given, those at smaller volumes from the isobars and those at larger volumes from the isotherms. The pressures read from the isothermals constructed from the data obtained by Thomas and myself by the modified Hofmann's vapour-density method are included in the second set.

Isobars, read from Isothermals.

Pressure in metres.	4	8	12	16	20	24	28	32	36	40	44	48	52	56
Temp.	Volume in cub. centims.													
10°	1·5871	1·5854	1·5838	1·5820	1·5806	1·5790	1·5773	1·5757	1·5742	1·5726	1·5711	1·5696	1·5682	1·5667
15·6	1·6012	1·5994	1·5976	1·5959	1·5941	1·5923	1·5906	1·5889	1·5872	1·5856	1·5839	1·5821	1·5806	1·5791
30	1·6388	1·6366	1·6344	1·6322	1·6300	1·6280	1·6260	1·6240	1·6220	1·6202	1·6184	1·6166	1·6149	1·6131
40	1·6681	1·6655	1·6630	1·6605	1·6581	1·6556	1·6533	1·6510	1·6487	1·6465	1·6444	1·6423	1·6402	1·6382
50	1·6984	1·6953	1·6924	1·6896	1·6868	1·6841	1·6814	1·6788	1·6763	1·6739	1·6715	1·6691	1·6668	1·6645
60	1·7312	1·7277	1·7244	1·7210	1·7179	1·7148	1·7116	1·7086	1·7057	1·7027	1·6999	1·6971	1·6944	1·6916
70	1·7666	1·7625	1·7585	1·7547	1·7510	1·7474	1·7440	1·7405	1·7372	1·7339	1·7306	1·7275	1·7244	1·7212
80	1·8038	1·7992	1·7948	1·7904	1·7861	1·7820	1·7780	1·7740	1·7700	1·7663	1·7625	1·7589	1·7552	1·7516
90	1·8477	1·8420	1·8364	1·8309	1·8255	1·8203	1·8154	1·8106	1·8060	1·8014	1·7974	1·7934	1·7893	1·7749
100	......	1·8896	1·8825	1·8760	1·8695	1·8634	1·8576	1·8516	1·8460	1·8406	1·8356	1·8306	1·8256	1·8008
110	......	1·9417	1·9334	1·9253	1·9176	1·9102	1·9029	1·8961	1·8895	1·8830	1·8771	1·8710	1·8652	1·8596
120	......	2·0037	1·9922	1·9815	1·9713	1·9615	1·9527	1·9445	1·9365	1·9287	1·9215	1·9150	1·9083	1·9015
130	......	......	2·0630	2·0485	2·0350	2·0230	2·0115	2·0005	1·9910	1·9810	1·9715	1·9630	1·9540	1·9463
140	......	......	2·1512	2·1290	2·1105	2·0940	2·0787	2·0650	2·0520	2·0405	2·0287	2·0185	2·0085	1·9987
150	......	......	......	2·2317	2·2035	2·1782	2·1565	2·1385	2·1210	2·1050	2·0912	2·0780	2·0655	2·0537
160	......	......	......	......	2·3285	2·2900	2·2575	2·2305	2·2062	2·1852	2·1657	2·1485	2·1322	2·1180
170	......	......	......	......	2·5252	2·4485	2·3882	2·3450	2·3080	2·2777	2·2512	2·2270	2·2057	2·1872
176	......	......	......	......	......	2·5800	2·4925	2·4315	2·3835	2·3440	2·3112	2·2837	2·2585	2·2362
180	......	......	......	......	......	2·7230	2·5835	2·5005	2·4405	2·3985	2·3550	2·3245	......	......
183	......	......	......	......	......	2·9050	2·6645	2·5590	2·4890	2·4335	2·3912	2·3550	2·3250	2·3000
185	......	......	......	......	......	3·1830	2·7345	2·6050	2·5270	2·4645	2·4165	......	......	......
186	......	......	......	......	......	......	2·7725	......	......	......	......	......	......	......
187·4	......	......	......	......	......	......	2·8360	......	......	......	......	......	......	......
187·8	......	......	......	......	......	......	2·8585	2·6770	2·5790	2·5075	2·4550	2·4115	2·3745	2·3445
190	......	......	......	......	......	......	......	2·7440	2·6260	2·5480	2·4880	2·4405	2·4000	2·3645
195	......	......	......	......	......	......	......	......	2·7580	2·6460	2·5700	2·5095	2·4610	2·4200
200	......	......	......	......	......	......	......	......	2·9355	2·7700	2·6650	2·5900	2·5305	2·4845
205	......	......	......	......	......	......	......	......	......	......	2·7790	2·6815	2·6110	......
210	......	......	......	......	......	......	......	......	......	......	2·9195	2·7930	2·6990	2·6200
220	......	......	......	......	......	......	......	......	......	......	......	......	2·9145	2·8045

Isochors, read from Isobars.

Pressure in metres.	4	8	12	16	20	24	28	32	36	40	44	48	52	56
Volume.	Temperature.													
	°	°	°	°	°	°	°	°	°	°	°	°	°	°
1·58	......	......	......	......	9·75	10·45	11·15	11·90	12·50	13·15	13·95	14·65	15·35	16·05
1·60	15·2	15·95	16·65	17 45	18·1	18·9	19·65	20·4	21·05	21·8	22·55	23·35	24·0	24·75
1·65	33·9	34·7	35·5	36·4	37·15	38·0	38·9	39·75	40·5	41·35	42·15	42·9	43·7	44·55
1·70	50·5	51·45	52·4	53·35	54·3	55·25	56·2	57·15	58·1	59·05	60·0	60·95	61·9	62·95
1·75	65·4	66·5	67·55	68 65	69·75	70·7	71·85	72·95	74·0	75·05	76·1	77·25	78·35	79·45
1·80	78·95	80·1	81·2	82·45	83·65	84·75	85·95	87·2	88·3	89·6	90·7	91·8	93·0	94·3
1·85	......	91·8	93·0	94·45	95·7	97·0	98·4	99·75	101·0	102·35	103·7	105·0	106·3	107·7
1·90	......	102·2	103·6	105·05	106·5	107·9	109·35	110·85	112·3	113·8	115·3	116·75	118·25	119·75
1·95	......	111·3	112·95	114·6	116·2	117·8	119·45	121·0	122·6	124·2	125·75	127·35	129·1	130·7
2·0	......	119·55	121·15	122·9	124 75	126·65	128·5	129·95	131·6	133·3	135·0	136·8	138·55	140·2
2·1	......	......	134·55	136·7	138·7	140·75	142·95	145·0	147·05	149·15	151·15	153·3	155·3	157·5
2·2	......	......	......	147·25	149·7	152·2	154·65	157·0	159·3	161·7	164·25	166·75	169·15	171·6
2·3	......	......	......	155·25	158·0	160·75	163·5	166·4	169·3	172·1	174·95	177·7	180·45	183·2
2·4	......	......	......	......	164·45	167·45	170·7	173·8	177·2	180·5	183·7	186·8	190·0	193·2
2·5	......	......	......	......	169·15	172·65	176·4	180·0	183·7	187·3	190·9	194·3	198·0	201·3
2·6	......	......	......	......	172·3	176·75	180·65	184·75	188·85	192·75	196·7	200·6	204·3	208·7
2·7	......	......	......	......	......	179·55	184·15	188·7	193·0	197·3	201·6	205·85	210·05	214·7
2·8	......	......	......	......	......	181·55	186·7	191·4	196·3	201·0	205·75	210·25	215·0	219·75

Isochors, read from Isothermals.

Vol....	2·4	2·5	2·6	2·7	2·8	2·9	3·0	3·2	3·4	3·6	3·8
Temp.	Pressures.										
170°	27060	21020	...	...	...	...	...	...	...	...	...
176	34520	27580	23360	21060	...	...	...	...	...	...	...
180	39400	32060	27380	24460	22830	...	...	...	...	...	...
183	43120	35280	30260	27050	25130	24010	23360	...	...	...	...
185	45680	37480	32280	28850	26710	25420	24660	...	...	...	...
187·8	49080	40560	34980	31270	28940	27420	26460	25490	25130	25050	25030
190·0	52000	43140	37280	33270	30730	29070	27860	26770	26270	26070	25960
195	...	48820	42320	37860	34880	32850	31460	29780	28940	28460	28190
200	...	54560	47480	42490	39100	36680	35010	32870	31660	30950	30480
205	...	...	...	47140	43270	40560	38550	35990	34430	33510	32820
210	...	...	...	51990	47700	44510	42160	39090	37260	36020	35140
220	...	...	...	...	...	52430	49630	45570	42940	41170	39910
230	...	...	...	...	...	...	...	52100	48860	46460	44680
240	...	...	...	..	...	...	...	...	..	51890	49690

Isochors, read from Isothermals.

Vol....	4·0	Approx. Crit. 4·3	4·6	5·0	5·5	6·0	6·5	7·0	7·5	8·0	8·5
Temp.	Pressures.										
180°	...	...	...	...	...	...	...	...	...	22230	21950
183	...	...	...	...	...	...	...	...	23090	22800	22490
185	...	...	...	...	...	...	23960	23770	23510	23200	22860
187·8	25020	25010	25000	24990	24940	24840	24660	24400	24070	23710	23330
190·0	25910	25860	25810	25760	25620	25420	25180	24880	24530	24110	23700
195	28000	27780	27650	27430	27130	26790	26420	26010	25570	25080	24590
200	30140	29730	29430	29060	28610	28150	27630	27100	26570	26010	25430
205	32310	31730	31260	30740	30070	29460	28840	28220	...	...	...
210	34460	33680	33070	32350	31540	30760	30010	29280	28530	27820	27110
220	38890	37640	36640	35580	34420	33350	32340	31380	30460	29600	28750
230	43280	41590	40280	38850	37290	35920	34680	33500	32400	31370	30400
240	47900	45770	44010	42130	40170	38500	37000	35610	34330	33140	32030
250	52360	49770	47740	45440	43030	41020	39270	37680	36240	34900	33660
260	...	53800	51380	48680	45890	43530	41480	39690	38080	36600	35220
270	...	...	...	51910	48750	46070	43780	41770	39980	38360	36860
280	...	...	...	...	51540	48580	46000	43750	41770	40000	38380

Isochors, read from Isothermals.

Vol. ...	9·0	9·5	10·0	11	12	13	14	15	16	17	18
Temp.	Pressures.										
150°	...	...	...	...	...	...	...	...	...	...	13430
160	...	...	...	...	...	...	16160	15620	15110	14620	14140
170	...	...	...	18950	18330	17710	17080	16490	15900	15330	14815
176	...	20700	20390	19720	19020	18330	18630	17000	16370	15780	15210
180	21630	21300	20950	20210	19470	18730	18010	17320	16670	16040	15470
183	22130	21770	21380	20590	19800	19030	18280	17570	16920	16270	15680
185	22490	22090	21690	20870	20040	19270	18480	17750	17060	16420	15840
187·8	22930	22560	22040	21160	20300	19500	18720	17980	17260	16600	15990
190·0	23250	22820	22360	21440	20560	19710	18910	18150	17440	16780	16150
195	24080	23570	23060	22060	21100	20200	19350	18550	17810	17110	16470
200	24870	24310	23760	22680	21670	20710	19810	18970	18180	17460	16800
210	26430	25770	25110	23880	22720	21670	20670	19780	18930	18140	17450
220	27950	27170	26430	25050	23770	22620	21560	20570	19650	18850	18050
230	29480	28600	27750	26200	24830	23550	22400	21350	20370	19500	18690
240	30990	30010	29090	27400	25890	24500	23250	22130	21110	20180	19330
250	32510	31430	30410	28570	26900	25460	24120	22940	21840	20850	19940
260	33970	32790	31690	29700	27940	26370	24970	23700	22560	21510	20540
270	35460	34180	33000	30870	28980	27300	25810	24480	23260	22160	21150
280	36920	35530	34240	31970	29970	28190	26620	25220	23970	22810	21770

Isochors, read from Isothermals.

Vol. ...	19	20	22	24	26	28	30	33	36	40	45
Temp.	Pressures.										
110°	...	...	...	..	...	...	...	...	...	6570	5995
120	...	...	...	...	...	...	...	7890	7400	6830	6235
130	...	...	...	...	...	9250	8825	8220	7705	7100	6465
140	...	...	11355	10745	10175	9665	9195	8555	8000	7365	6700
150	13020	12630	11890	11215	10600	10035	9530	8870	8295	7625	6920
160	13685	13260	12440	11720	11050	10465	9930	9205	8595	7880	7140
170	14310	13835	12960	12180	11480	10845	10275	9530	8880	8130	7360
176	14680	...	...	...	...	...	...	...	...	...	...
180	14920	14405	13480	12650	11900	11225	10635	9855	9160	8380	7575
183	15100	...	...	...	...	...	...	...	...	...	...
185	15230	...	...	...	...	...	...	...	...	...	...
187·8	15400	...	...	...	...	...	...	...	...	...	...
190·0	15540	14985	...	...	...	...	...	...	...	...	...
195	15870	...	...	...	...	...	...	...	...	...	...
200	16150	15550	14480	13525	12700	11980	11325	10460	9705	8870	8000
210	16760	16110	...	...	...	...	...	...	...	...	...
220	17350	16690	15480	14445	13525	12730	12025	11075	10275	9380	8440
230	17950	17250	...	...	...	...	...	...	...	...	...
240	18530	17800	16480	15340	14360	13475	12705	11700	10845	9875	8875
250	19100	...	...	...	...	...	...	...	...	...	...
260	19670	18880	17470	16210	15140	14210	13390	12330	11425	10380	9305
270	20250	...	...	...	...	...	...	...	...	...	...
280	20820	19970	18450	17120	15990	14995	14095	12960	11990	10920	9775

Isochors, read from Isothermals.

Vol. ...	50	60	70	80	90	100	120	140	160	180	200
Temp.	Pressures.										
50°	...	...	...	...	...	...	...	...	...	1438	1305
60	...	...	...	...	...	...	...	1880	1665	1491	1354
70	...	...	...	...	...	2633	2240	1947	1720	1544	1400
80	...	...	...	3321	3000	2738	2315	2015	1780	1594	1443
90	...	...	3865	3452	3110	2835	2400	2081	1837	1643	1489
100	5295	4575	4015	3565	3215	2932	2480	2152	1897	1695	1532
110	5510	4745	4150	3698	3327	3030	2558	2217	1953	...	...
120	5720	4910	4295	3820	3440	3117	2637	2283	2009	1796	1622
130	5930	5080	4435	3938	3537	3212	2711	2348	2062	...	...
140	6135	5240	4570	4055	3645	3303	2790	2413	2120	1896	1714
150	6330	5400	4715	...	...	...	...	...	...	...	...
160	6525	5560	4850	4295	3850	3492	2943	2545	2234	1995	1805
170	6725	5725	4990	...	...	...	...	...	...	...	...
180	6920	5880	5110	4522	4052	3667	3093	2666	2345	2096	1894
200	7290	6185	5375	4757	4257	3855	3240	2800	2458	2194	1981
220	7675	6500	5635	4993	4475	4043	3393	2926	2566	2290	2066
240	8060	6820	5905	...	...	...	...	...	...	...	...
250	...	...	...	5325	4765	4310	3622	3130	2739	2435	2200
260	8455	7145	6165	...	...	...	...	...	...	...	...
280	8850	7460	6450	5685	5085	4588	3848	3320	2907	2584	2334

Isochors, read from Isothermals.

Vol. ...	230	260	300	350	400	500	600	700	800	900	1000
Temp.	Pressures.										
10·75°	...	...	...	...	...	...	398	342·5	300	268	241·5
30	...	...	...	719	633·5	509	426	366·5	322	286·5	258·5
40	1105	985	860	743·5	654	526	440·5	380	333·5	296·5	267
50	1145	1020	890	769	675·5	544	454·5	391·5	344	305·5	275
60	1186	1054	917	795	699	561·5	470·5	404	355	316	284·5
70	1225	1092	952	820	720	580	484·5	416·5	365·5	325	293·5
80	1262	1124	979	844	743·5	596·5	500	429·5	376	335	302
90	1301	1158	1010	869	764·5	615	514	441·5	387·5	345	311
100	1343	1194	1038	895	787	634	528·5	454	398·5	354·5	319·5
110	...	...	...	...	809·5	650	543·5	467	409·5	364·5	328·5
120	1420	1262	1097	947	831	670	559·5	479·5	420·5	374	337
130	...	...	...	...	854·5	686	574	493	431·5	384	346
140	1497	1332	1156	995	876·0	704·5	588·5	505	443·5	395	355
150	...	...	...	...	899·5	723·5	604·5	518·5	454	403·5	363·5
160	1576	1400	1216	1046	916	...	...	...	...	...	...
180	1654	1467	1275	1095	964	...	...	...	...	...	...
200	1728	1535	1334	146	1005	...	...	...	...	...	...
220	1806	1603	1394	194	1047	...	...	...	...	...	...
250	1921	1706	1481	1272	1114	...	...	...	...	...	...
280	2036	1806	1568	1349	1182	...	...	...	...	...	...

Isochors, read from Isothermals.

Vol. …	1200	1400	1600	1800	2000	2300	2600	3000	3500	4000
Temp.	Pressures.									
10·75°	202·0	...	...	...	...	...	...	...	...	...
11·0	202·0	173·5	151·8	135·1	121·8	106·2	94·2	81·6	70·0	61·3
16·3	205·5	177·0	154·9	137·8	124·0	108·1	95·8	83·0	71·4	62·4
30	215·8	185·5	162·4	144·4	130·1	113·5	100·6	87·3	74·7	65·3
40	223·0	191·5	168·0	149·8	134·8	117·3	104·1	90·4	77·5	67·7
50	230·0	197·5	173·3	154·3	139·2	121·0	107·2	93·3	79·9	69·8
60	237·3	204·2	178·7	158·9	143·1	124·7	110·3	96·0	82·2	71·8
70	245·0	210·0	184·0	163·4	147·5	128·7	113·8	98·8	84·8	74·2
80	251·6	215·7	189·4	168·4	151·8	132·1	117·2	101·9	87·3	76·2
90	259·2	223·5	195·3	173·9	156·6	136·1	120·7	105·1	89·9	78·5
100	266·7	229·7	200·9	179·0	160·7	140·0	124·3	108·0	92·4	80·4
110	273·5	...	...	...	...	...	...	...	...	...
120	280·5	...	...	...	...	...	...	...	...	...
130	288·5	...	...	...	...	...	...	...	...	...
140	296·0	...	...	...	...	...	...	...	...	...
150	303·0	...	...	...	...	...	...	...	...	...

The values of $\frac{dp}{dt}$ (b in the equation $p=b\mathrm{T}-a$) have been calculated from the data given in the preceding tables, and as they are not quite constant at all volumes it seems necessary to give them in detail so as to indicate the nature of the variations. This, however, has not been done for volumes below 2·4 cub. centim., for which the values of $\frac{dp}{dt}$ were obtained from the isobars, because the deviations are within the limits of experimental error.

Values of $\frac{dp}{dt}$ $(=b)$ from Isochors.

Vol. ...	2·4	2·5	2·6	2·7	2·8	2·9	3·0	3·2	3·4	3·6	3·8
Temp.											
170°											
	1243	1093	...	...	...	...	...	...	...	...	...
176											
	1220	1120	1005	850	...	...	...	...	...	...	...
180											
	1240	1073	960	863	767	...	...	...	...	...	...
183											
	1280	1100	1010	900	790	705	650	...	...	...	...
185											
	1214	1100	964	864	796	714	643	...	...	...	...
187·8											
	1327	1173	1045	909	814	750	636	577	518	464	423
190											
	...	1136	1008	918	830	756	720	602	534	478	446
195											
	...	1148	1032	926	844	766	710	618	544	498	458
200											
	...	...	...	930	834	776	708	624	554	512	468
205											
	...	...	...	970	886	790	722	620	566	502	464
210											
	...	...	...	...	...	792	747	648	568	515	477
220											
	...	...	...	...	...	...	...	653	592	529	477
230											
	...	...	...	...	...	...	...	...	...	543	501
240											

Values of $\frac{dp}{dt}$ $(=b)$ from Isochors.

Vol. ...	4·0	4·3	4·6	5·0	5·5	6·0	6·5	7·0	7·5	8·0	8·5
Temp.											
180°											
	...	...	...	...	...	...	...	...	...	190	180
183											
	...	...	...	...	...	...	...	...	210	200	185
185											
	...	...	...	...	...	...	250	225	200	182	168
187·8											
	405	386	368	350	309	264	236	218	209	182	167
190											
	418	384	368	334	302	274	248	226	208	194	198
195											
	428	390	356	326	296	272	242	222	200	186	168
200											
	434	400	366	336	292	262	242	224	196	181	168
205											
	430	390	362	322	294	260	234	212			
210											
	443	396	357	323	288	259	233	210	193	178	164
220											
	439	395	364	327	287	257	234	212	194	177	165
230											
	462	418	373	328	288	258	232	211	193	177	163
240											
	446	400	373	331	287	252	227	207	191	176	163
250											
	...	403	364	324	286	251	221	201	184	170	156
260											
	...	...	...	323	286	254	230	208	190	176	164
270											
	..	...	...	...	279	251	222	198	179	164	152
280											

Values of $\frac{dp}{dt}$ $(=b)$ from Isochors.

Vol. ...	9·0	9·5	10	11	12	13	14	15	16	17	18
Temp.											
150°											
	...	...	...	...	...	...	...	...	...	...	71
160											
	...	...	...	...	...	...	92	87	79	71	67·5
170											
	...	...	...	126	114	102	93	83	77	71	65·5
180											
	172	158	148	132	114	104	94	86	78	76	68
185											
	152	146	134	114	104	92	86	80	76	72	64
190											
	166	150	140	124	108	98	88	80	74	66	68
195											
	158	148	140	124	114	102	92	84	74	70	66
200											
	156	146	135	120	105	96	86	81	75	68	63
210											
	152	140	132	117	105	95	89	79	72	69	62
220											
	153	143	132	115	106	93	84	78	72	67	64
230											
	151	141	134	120	106	95	85	78	74	68	64
240											
	152	142	132	117	101	96	87	81	73	67	61
250											
	146	136	128	113	104	91	85	76	72	66	60
260											
	149	139	131	117	104	93	84	78	70	65	61
270											
	146	135	124	108	99	89	81	74	71	65	62
280											

Values of $\frac{dp}{dt}$ $(=b)$ from Isochors.

Vol....	19	20	22	24	26	28	30	33	36	40	45
Temp.											
110°											
	...	...	...	...	...	...	...	...	...	26	24
120											
	...	...	...	...	...	...	...	33	30·5	27	23
130											
	...	...	...	...	...	41·5	37	33·5	29·5	26·5	23·5
140											
	...	...	53·5	47	42·5	37	33·5	31·5	29·5	26	22
150											
	66·5	63	55	50·5	45	43	40	33·5	30	25·5	22
160											
	62·5	57·5	52	46	43	38	34·5	32·5	28·5	25	22
170											
	61	57	52	47	42	38	36	32·5	28	25	21·5
180											
	62	58	50	43·7	45	37·8	34·5	30·2	27·8	24·5	21·2
190											
	61	56·5									
200											
	61	56	50	46	41·2	37·5	35	30·8	28·5	25·5	22
210											
	59	58									
220											
	60	56	50	44·8	41·8	37·2	34	31·2	28·5	24·8	21·8
230											
	58	55									
240											
	57	54	49·5	43·5	39	36·8	34·8	31·5	29	25·2	21·5
250											
	57										
260											
	58	54·5	49	45·5	42·5	39·7	35·2	31·5	28·2	27	23·5
270											
	57										
280											

Values of $\frac{dp}{dt}$ $(=b)$ from Isochors.

Vol.... Temp.	50	60	70	80	90	100	120	140	160	180	200
50°	...	...	...	...	...	...	...	...	...	5·3	4·9
60	...	...	...	...	...	...	...	6·7	5·5	5·3	4·6
70	...	...	...	...	...	10·5	7·5	6·8	6·0	5·0	4·3
80	...	...	...	13·1	11·0	9·7	8·5	6·6	5·7	4·9	4·6
90	...	...	15·0	11·3	10·5	9·7	8·0	7·1	6·0	5·2	4·3
100	21·5	17·0	13·5	13·3	11·2	9·8	7·8	6·5	5·6	5·05	4·5
110	21·0	16·5	14·5	12·2	11·3	9·7	7·9	6·6	5·6		
120	21·0	17·0	14·0	11·8	9·7	9·5	7·4	6·5	5·3	5·0	4·6
130	20·5	16·0	13·5	11·7	10·8	9·1	7·9	6·5	5·8		
140	19·5	16·0	14·5	12·0	10·25	9·45	7·65	6·6	5·7	4·95	4·55
150	19·5	16·0	13·5								
160	20·0	16·5	14·0	11·35	10·1	8·75	7·5	6·05	5·55	5·05	4·45
170	19·5	15·5	12·0								
180	18·5	15·25	13·25	11·75	10·25	9·4	7·35	6·7	5·65	4·9	4·35
200	19·25	15·75	13·0	11·8	10·9	9·4	7·65	6·3	5·4	4·8	4·25
220	19·25	16·0	13·5	11·07	9·67	8·9	7·63	6·8	5·77	4·83	4·47
240	19·75	16·25	13·0								
250	...			12·0	10·67	9·25	7·53	6·33	5·6	4·97	4·47
260	19·75	15·75	14·25								
280											

Values of $\frac{dp}{dt}$ $(=b)$ from Isochors.

Vol.…	230	260	300	350	400	500	600	700	800	900	1000
Temp.											
10°·75											
11											
16·3							1·45	1·25	1·14	·96	·88
30											
	…	…	…	2·45	2·05	1·7	1·45	1·35	1·15	1·0	·85
40											
	4·0	3·5	3·0	2·55	2·15	1·8	1·4	1·15	1·05	·9	·9
50											
	4·1	3·4	2·7	2·6	2·35	1·75	1·6	1·25	1·1	1·05	·95
60											
	3·9	3·8	3·5	2·5	2·1	1·85	1·4	1·25	1·05	·9	·9
70											
	3·7	3·2	2·7	2·4	2·35	1·65	1·55	1·3	1·05	1·0	·85
80											
	3·9	3·4	3·1	2·5	2·1	1·85	1·4	1·2	1·15	1·0	·9
90											
	4·2	3·6	2·8	2·6	2·25	1·9	1·45	1·25	1·1	·95	·85
100											
					2·25	1·6	1·5	1·3	1·1	1·0	·9
110	3·85	3·4	2·95	2·6							
					2·15	2·0	1·6	1·25	1·1	·95	·85
120											
					2·35	1·6	1·45	1·35	1·1	1·0	·9
130											
	3·85	3·5	2·95	2·4	2·15	1·85	1·45	1·2	1·2	1·1	·9
140											
					2·35	1·9	1·6	1·35	1·05	·85	·85
150											
	3·95	3·4	3·0	2·55	1·65	…	…	…	…	…	…
160											
	3·9	3·35	2·95	2·45	2·4	…	…	…	…	…	…
180											
	3·7	3·4	2·95	2·55	2·05	…	…	…	…	…	…
200											
	3·9	3·4	3·0	2·4	2·1	…	…	…	…	…	…
220											
	3·83	3·43	2·9	2·6	2·23	…	…	…	…	…	…
250											
	3·83	3·33	2·9	2·57	2·27	…	…	…	…	…	…
280											

Values of $\frac{dp}{dt}$ $(=b)$ from Isochors.

Vol. ...	1200	1400	1600	1800	2000	2300	2600	3000	3500	4000
Temp.										
10°·75	·64									
11·0		·66								
16·3			·58	·51	·42	·36	·30	·26	·26	·21
30	·75	·62	·55	·50	·45	·39	·35	·31	·24	·21
40	·72	·60	·56	·54	·47	·38	·35	·31	·28	·24
50	·70	·60	·53	·45	·44	·37	·31	·29	·24	·21
60	·73	·67	·54	·46	·39	·37	·31	·27	·23	·20
70	·77	·58	·53	·45	·44	·40	·35	·28	·26	·24
80	·66	·57	·54	·50	·43	·34	·34	·31	·25	·20
90	·76	·78	·59	·55	·48	·40	·35	·32	·26	·23
100	·75	·62	·56	·51	·41	·39	·36	·29	·25	·19
110	·68	...	...	...	...	...	...	...	...	...
120	·70	...	...	...	...	...	...	...	...	...
130	·80	...	...	...	...	...	...	...	...	...
140	·75	...	...	...	...	...	...	...	...	...
150	·70	...	...	...	...	...	...	...	...	...

It will be seen from the preceding tables that the values of $\frac{dp}{dt}$ $(=b)$ are nearly but not quite constant. At volumes lower than 4·6 cub. centim. (the critical volume of a gram $=4·266$ cub. centim.) the values of b increase with rise of temperature, whilst at greater volumes (up to about 400 cub. centim.) they diminish. At still larger volumes they appear to be constant, at any rate the deviations are within the limits of experimental error.

These deviations of b from constancy appear to be far too regular to be attributed to experimental error, and the results seem to confirm the conclusion arrived at by Amagat in the case of the substances examined by him, that the values of b are not absolutely constant.

It is noteworthy that with isopentane the isochor for a volume very slightly higher than the critical volume is straight, whilst those on either side are slightly curved in opposite directions.

It is also noticeable that the variations in the values of b diminish as the temperature rises, and, indeed, that at volumes higher than 30 cub. centim. they practically disappear at the higher temperatures.

This also agrees with Amagat's conclusions from his observations with carbon dioxide, ethylene, and other gases ("Mémoires sur l'élasticité et la dilatabilité des Fluides jusqu' aux très hautes Pressions," *Ann. Chim. Phys.* 6th Series, vol. xxix. p. 67) :—"Il parait résulter de l'ensemble de ces résultats que les variations du coefficient de pression avec la température, *toujours très petites*, s'annulent aux températures suffisamment élevées et probablement à toutes les températures, sous des pressions suffisantes ; c'est bien ce que paraissent montrer les résultats relatifs à ceux des gaz qui, dans les limites de température de ce travail, sont déjà beaucoup au-dessus de leur température critique."

The temperatures and pressures at the volumes given in the tables were mapped, and straight lines drawn to pass as well as possible through the points. From these straight lines the values of b were obtained, and they are given in the following table (pp. 650, 651). As the values of b tend to become constant at high temperatures, they have also been calculated for volumes from 2·4 to 400 cub. centim. from the observations at the three highest temperatures, and these are also given.

At lower volumes than 2·4 cub. centim. the isochors were obtained indirectly from the isobars, and at higher volumes than 400 cub. centim. the variations are within the limits of experimental error.

The values of b cannot well be mapped against the volume, but I have adopted the suggestion of Rose-Innes and plotted the values of $\frac{10000}{bv}$ against $v^{-1/3}$ (fig. 3, p. 652).

At the largest volumes the value of $\frac{10000}{bv}$ becomes very nearly constant and agrees closely with that (11·6) calculated from the molecular weight of isopentane.

	b.		$\frac{10000}{bv}$.	
Volume of a gram in cub. centim.	From drawn Isochors.	From observations at three highest temperatures.	From drawn Isochors.	From observations at three highest temperatures.
1·58	5711	......	1·108	......
1·6	5450	......	1·147	......
1·65	4823	......	1·257	......
1·7	4202	......	1·400	......
1·75	3712	......	1·540	......
1·8	3390	......	1·639	......
1·85	3014	......	1·794	......
1·9	2734	......	1·925	......
1·95	2475	......	2·072	......
2·0	2309	......	2·165	......
2·1	1914	......	2·487	......
2·2	1644	......	2·764	......
2·3	1425	......	3·051	......
2·4	1238	1274	3·365	3·27
2·5	1111	1152	3·602	3·47
2·6	998·5	1028	3·851	3·74
2·7	913·0	942	4·056	3·93
2·8	834·5	855	4·279	4·18
2·9	763·0	786	4·520	4·39
3·0	704·5	726	4·731	4·59
3·2	627·0	640	4·986	4·88
3·4	557·0	575	5·281	5·12
3·6	509·5	529	5·455	5·25
3·8	468·0	485	5·507	5·43
4·0	436·0	449	5·733	5·57
4·3	397·0	407	5·859	5·71
4·6	363·9	370	5·973	5·88
5·0	327·1	326	6·114	6·14
5·5	288·7	284	6·298	6·40
6·0	256·8	252	6·489	6·61
6·5	232·1	224	6·628	6·87
7·0	210·5	202	6·786	7·07
7·5	192·6	184	6·925	7·25
8·0	177·4	170	7·046	7·35
8·5	164·3	157	7·195	7·49
9·0	152·3	147	7·294	7·56
9·5	141·8	137	7·424	7·68
10	132·6	128	7·541	7·81
11	118·0	112·7	7·705	8·07
12	105·3	102·3	7·917	8·15
13	95·11	91·0	8·088	8·45
14	86·67	83·3	8·258	8·58
15	79·37	76·0	8·400	8·77
16	73·86	71·0	8·463	8·80
17	68·26	65·3	8·618	9·01
18	63·31	61·0	8·698	9·11
19	59·63	57·3	8·835	9·18
20	56·36	54·5	8·872	9·18
22	50·62	49·5	8·979	9·18
24	45·31	44·6	9·196	9·34
26	41·30	41·1	9·314	9·36
28	38·11	37·9	9·372	9·42
30	35·20	34·7	9·470	9·61
33	31·77	31·4	9·539	9·65
36	28·57	28·6	9·722	9·71

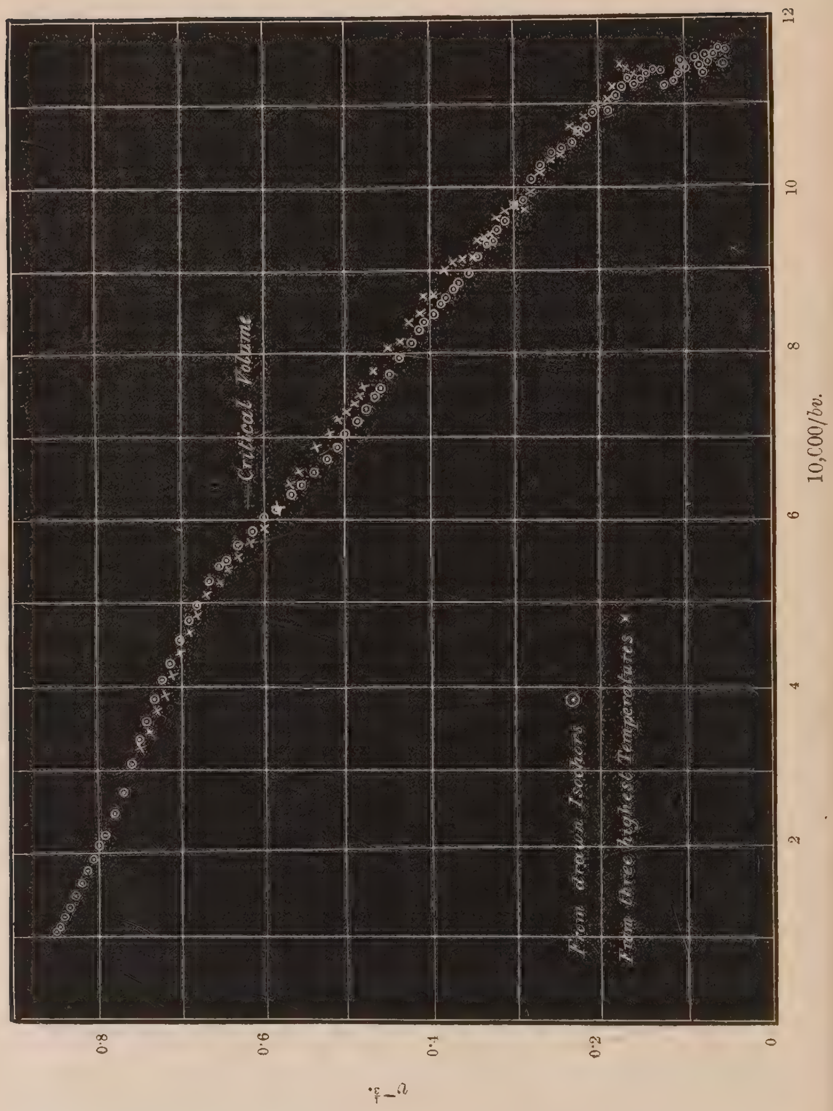
Table (*continued*).

	b.		$\frac{10000}{bv}$.	
Vol. of gram in c.c.	From drawn Isochors.	Obs. at 3 highest temps.	From drawn Isochors.	Obs. at 3 highest temps.
40	25·48	25·7	9·813	9·73
45	22·03	22·3	10·09	9·97
50	19·49	19·6	10·26	10·21
60	15·94	16·0	10·46	10·42
70	13·56	13·6	10·53	10·50
80	11·92	11·62	10·49	10·76
90	10·47	10·41	10·61	10·67
100	9·31	9·18	10·74	10·89
120	7·66	7·60	10·87	10·97
140	6·54	6·48	10·92	11·02
160	5·64	5·59	11·07	11·18
180	4·97	4·87	11·18	11·41
200	4·45	4·40	11·24	11·36
230	3·887	3·85	11·18	11·29
260	3·427	3·39	11·22	11·35
300	2·957	2·93	11·27	11·38
350	2·521	2·52	11·33	11·34
400	2·188 2·222	2·20	11·43 11·25	11·36 ......
500	1·792	......	11·16	......
600	1·485	......	11·22	......
700	1·261	......	11·33	......
800	1·095	......	11·42	......
900	0·977	......	11·37	......
1000	0·881	......	11·35	......
1200	0·727	......	11·45	......
1400	0·626	......	11·41	......
1600	0·549	......	11·37	......
1800	0·483	......	11·51	......
2000	0·437	......	11·45	......
2300	0·377	......	11·53	......
2600	0·332	......	11·58	......
3000	0·292	......	11·40	......
3500	0·251	......	11·39	.....
4000	0·216	......	11·58	......

A curve drawn through the points obtained from the drawn isochors shows a decided hump in the neighbourhood of the critical volume, and, in this respect, resembles that constructed from the data obtained by Ramsay and myself with ether. With the values of $\frac{10000}{bv}$ calculated from the observations at the highest temperatures the hump becomes far less marked but does not disappear; with the values derived from the observations at the lowest temperatures it would be greatly exaggerated.

It is possible that at still higher temperatures the curve might become quite smooth, but unfortunately above 280°

Fig. 3.


Critical Volume
From drawn Isochors ⊙
From three highest Temperatures ×
0·8
0·6
0·4
0·2
0
2
4
6
8
10
12
10,000/bv.
$v^{-\frac{1}{3}}$.

PHYSICAL SOCIETY OF LONDON.

ABSTRACTS OF PHYSICAL PAPERS

FROM FOREIGN SOURCES.

NOVEMBER 1895.

GENERAL PHYSICS.

694. *Observation of Torsional Vibrations.* **R. W. Wood.** (Wied. Ann. 56. pp. 171–172, 1895.)—This is a simple method of observing oscillations in which the seconds-hand of the watch and the vibrating body can be observed at the same time, thus obviating the necessity of a stopwatch. A mirror is attached to the vibrating body, which reflects the light of a lamp placed near the telescope into the observer's eye at the instant when the mean position is passed. Between the mirror and the telescope a piece of plain glass, thinly platinised, is introduced, at an angle of 45° to the vertical, which allows the flash to pass, but at the same time reflects the image of a watch lying on a table below. The observer notes the exact time indicated by the enlarged seconds-hand when the flash appears. With a little practice this may be done to within a fifth of a second. The seconds-hand appears of course to move counter-clockwise, but it is easy to get accustomed to that.
E. E. F.

[This method may be simplified by allowing the flash to fall upon the watch direct, and reading the time at which it is illuminated. But here a difficulty lies in the fact that the light moves across the face of the watch. It is therefore better to catch the flash on a piece of white cardboard which reflects the diffused light on to the face of the watch. The latter may be observed through a lens. By varying the size of the cardboard and its distance from the mirror, the intensity and duration of illumination may be regulated at will.—E. E. F.]

695. *Compressibility of Solutions.* **G. Tammann.** (Zschr. phys. Chem. 17. pp. 620–636, 1895.)—This memoir consists of calculations based on the "law of congruence" for solutions; according to which the thermodynamic surface ($f(p, v, \theta)=0$) for a solution is identical with that of the solvent displaced along the axis of pressure, by a certain amount, say $\Delta \mathrm{K}$, provided the unit of volume is taken to be the volume of the liquid, under no pressure, in each case. If we look upon the volume of a liquid as determined by the sum of its internal pressure K, and the external pressure p applied to it, we may regard $\Delta \mathrm{K}$ as the excess of internal pressure produced by the salt in solution. It follows that if the pressure on a substance obeying the law of congruence is raised from 0 to p, the total internal pressure is raised from $\mathrm{K}+\Delta \mathrm{K}$ to $\mathrm{K}+\Delta \mathrm{K}+p$, and the fractional compression produced is the same as that occurring in the solvent when its external pressure is raised from $\Delta \mathrm{K}$ to $\Delta \mathrm{K}+p$. Now Amagat's measurements of the isothermals of water are expressible by

$$v_p-v_0=\mathrm{A}\{\log_{10}(\mathrm{B}+p)-\log \mathrm{B}\}v_0,$$

where v_0 is the volume under no pressure, and A B are constants. Hence the volume of a salt solution $v_{\Delta \mathrm{K},p}$ should be expressible by

$$v_{\Delta \mathrm{K},p}-v_{\Delta \mathrm{K},0}=\mathrm{A}\{\log_{10}(\mathrm{B}+\Delta \mathrm{K}+p)-\log_{10}(\mathrm{B}+\Delta \mathrm{K})\}v_{\Delta \mathrm{K}=p=0}.$$

In the last expression $v_{\Delta \mathrm{K}=p=0}$ means the volume which the solution would, according to the law of congruence, occupy if its total internal pressure ($\mathrm{K}+\Delta \mathrm{K}+p$) could be reduced to the value it possesses in the uncompressed solvent, viz.: K. That is, according to Amagat's results,

$$v_{\mathrm{K}\ =p=0}=\frac{v_{\Delta \mathrm{K},0}}{1-\mathrm{A}\{\log(\mathrm{B}+\Delta \mathrm{K})-\log \mathrm{B}\}}.$$

Thus finally

$$v_{\Delta \mathrm{K},p}-v_{\Delta \mathrm{K},0}=\frac{\mathrm{A}\{\log(\mathrm{B}+\Delta \mathrm{K}+p)-\log(\mathrm{B}+\Delta \mathrm{K})\}v_{\Delta \mathrm{K},0}}{1-\mathrm{A}\{\log(\mathrm{B}+\Delta \mathrm{K})-\log \mathrm{B}\}}.$$

The author first gives a comparison of Amagat's numbers with the results of the formula, the agreement being fairly close, and finds :—

Temp. °	A.	B (atmos.).	v_0.
0	0·29387	2447	1·00018
5	0·29202	2497	1·00006
10	0·28653	2512	1·00031
20	0·28401	2565	1·00180
30	0·28274	2600	1·00436

Now to determine the internal pressure $\Delta \mathrm{K}$ of a solution as compared with the solvent, it is only necessary to determine the thermal expansion of a solution under no pressure (or atmospheric pressure) and compare it with the sheaf of isobars for water; it will agree with the expansion indicated by one of these, and the pressure of that isobar will be the value of ΔK. ΔK is not quite a linear function of the concentration, and amounts to 700 to 1100 atmos. for normal solutions of ordinary salts. It is thus possible to determine the compressibility of a solution by means of its thermal expansion, and avoid the great difficulties of the direct measurement. Tables are given for NaCl, $MgSO_4$, $(NH_4)_2SO_4$, KI, and $BaCl_2$, with the experimental numbers of Tait for comparison.

The law of congruence, however, is only a first approximation; the author proceeds to show how to take into account the small deviations from it. These tend, in each case considered, to lessen the calculated compressions; in that way a more satisfactory agreement with experiment is obtained. R. A. L.

696. *Plasticity of Ice.* **O. Mügge.** (Nach. G. Wiss. Göttingen, pp. 173–176, 1895.)—In corroboration of the results of McConnel (Proc. Roy. Soc. 48. p. 259, 1890; and 49. p. 323, 1891), experiments are made upon the bending of small bars of ice, held horizontally, supported at the ends, and loaded at the middle. If such a bar, or crystal, is so cut that the optical axis is perpendicular to the length, the load causes considerable bending; but a rod having the optical axis horizontal shows no appreciable bending under these conditions. This agrees with the supposition that the crystals consist of thin laminæ, formed of a flexible but almost inextensible substance, the interspaces being filled with a separating medium which is sufficiently viscous to retard the mutual gliding of the plates. Ice, in this respect, resembles $KMnCl_3 . 2aq.$, where the deformation results, similarly, from a motion of translation of the component laminæ, retarded by viscous matter in the interspaces. The experiments seem to show that this motion of translation takes place with equal facility in all directions parallel to the end surfaces; and, within the limits of −3° C. and −16° C., the extent of the motion, for a given load, appears to be independent of temperature. R. A.

697. *Theory of Gases and Liquids.* **G. Bakker.** (Zschr. phys. Chem. 17. pp. 678–688, 1895.)—Some well-known results are here obtained in rather clumsy fashion, the reasoning being so ordered that it is difficult to make out precisely the assumptions upon which any particular result depends; and the conclusion is stated that (1) Joule's law, expressed by $\epsilon=f(t)$, (2) Boyle-van der Waals' law, $p(v-b)=\phi(t)$, (3) Gay Lussac-van der Waals' law, $v-b=t\psi(p)$, (4) the law of the dependence of c_p and c_v on temperature alone, (5) the law of the constancy of c_p-c_v, are so related that each law entails the other four—which is not true except under certain assumed conditions. Joule's law *by itself*, for instance, gives nothing but the dependence of c_v on temperature only, and of p/t on density only; Boyle-van der Waals' law gives nothing but the dependence of c_p-c_v on temperature only, unless $\phi(t)\propto t$ or some other equivalent relation holds; and so on: the whole of the

reasoning has in fact been founded on the initial assumption of law (4) and of the absence of molecular action. A calculation is then made of the contraction that accompanies the mixture of two liquids and its agreement with a law of van't Hoff is shown, and the theorem is given that the pressure of a fluid at constant volume and its co-volume at constant pressure would be increased in the same ratio by the removal of molecular action. R. E. B.

---

698. *Influence of Pressure on the Electric Conductivity of Solutions.* **G. Tammann.** (Zschr. phys. Chem. 17. pp. 725–736, 1895.)—If $\frac{1}{\lambda}\frac{\partial\lambda}{\partial p}$ is plotted as a function of m, the curve is a complicated one (λ=conductivity, m=concentration); that is because the change in conductivity is due to three causes:—1st, pressure reduces the volume, and so by bringing more ions into a cubic centimetre increases the conductivity; 2nd, it changes the viscosity (for low pressures the viscosity of water is diminished by pressure, and so the conductivity increased); 3rd, pressure increases the dissociation constant, and so the conductivity. The first two effects, in solutions, depend on the internal pressure (ΔK) of the solution: *e.g.* if $\Delta K=1000$ atmos., a rise of external pressure from 0 to 100 will only produce the same effect as would, in water, a rise of pressure from 1000 to 1100 atmos. (see Tammann in Zschr. phys. Chem. 13. p. 174, 1894). The volume effect is thus less for strong solutions (ΔK large) than for weak ones; but always remains +ve. The viscosity effect is reduced, and changes sign at about $\Delta K=800$ atmos., after which pressure increases the viscosity. For very dilute solutions the dissociation is already complete, and the third effect therefore vanishes: in that case 500 atmos. external pressure produces 2·2 per cent. decrease of volume, and 2·3 per cent. decrease of viscosity, giving 4·5 per cent. increase of conductivity. This is confirmed by Röntgen's experiments on NaCl and KCl.—It has been shown that the dissociation of 1 gm.-molecule of a binary electrolyte produces a contraction of about 10 c.c. in its solution. Pressure therefore favours the dissociation; the exact relation is given by

$$\frac{\partial \log_e k}{\partial p} = -\frac{\Delta v}{1000\,\mathrm{RT}},$$

where k is the dissociation constant and $\Delta v=-10$ c.c. This gives at 18° an increase of 23·35 per cent. in k for 500 atmos. The resulting increase of dissociation is tabulated for various values of k and v: it amounts to 10 per cent. when $kv=0·01$; its greatest value is a little over 11 per cent. Curves are then drawn showing the total value of $\frac{100}{\lambda}\frac{\partial\lambda}{\partial p}$ (say $\partial q/\partial p$) in its relation to the concentration for strong, medium, and weak dissociated electrolytes. The author proceeds to show that, according to the law of congruence,

$$\frac{\partial K}{\partial m} = \frac{\partial(\partial q/\partial p)}{\partial m} \Big/ \frac{\partial^2 q}{\partial p^2}.$$

Now as the left-hand expression is always +ve, it follows that $\partial^2 q/\partial p^2$ is +ve so long as $\partial q/\partial p$ increases with concentration, and *vice versâ*. Instances are quoted, supporting this conclusion by experiment. R. A. L.

---

699. *Stresses produced in a Continuous Girder owing to Differences of Temperature between the Flanges.* **Deslandres.** *Note on the preceding.* **M. Lévy.** (C. R. 121. pp. 414–421, 1895.)—The first-named author shows that differences in temperature between the upper and lower flanges of a continuous girder produce strains in the material, owing to the tendency of the heated portion to expand, of the cooled portion to contract. He obtains an idea of the order of magnitude of the forces brought into play by considering the case of a beam rigidly fixed at both ends. Experiments made on the bridge of Bezons, which spans a small tributary of the Seine, showed differences of temperature of about 14° C., which the calculations show should produce tensions and compressions equal to 1·7 kg. per sq. mm., or, allowing for the rivet-holes, about 2 kg. per mm., a magnitude about $\frac{1}{3}$ of the maximum fixed by the circular of 31st Aug., 1891—presumably issued by a body corresponding to our Board of Trade.

The second-named writer deals with the problem in a more complete manner: he considers (1) a girder fixed at one extremity and supported on rollers at the other; (2) a girder fixed at both ends; (3) a continuous girder of many spans fixed at one end and supported on rollers at the other supports. The complete formulæ, which are very clearly expressed, showed that in many cases the forces called into action are even greater than those indicated by Deslandres. A. Gs.

---

700. *Mont Blanc Observatory in* 1895. **J. Janssen.** (C. R. 121. pp. 391–392, 1895.)—Janssen announces under date of Aug. 31, that Bigourdan, of the Paris observatory, has made gravitation-tests at Chamounix and on the Grands Mulets (3050 m.) with an instrument lent by the Minister for War, and that Thierry has spent one day on the summit, conducting bacteriological and ozone tests. In spite of the frequent storms, the transport of the heavy instruments up to the summit has been effected without any injury to the porters. No details are given. H. B.

---

701. *Comparisons of Length.* **B. Pensky.** (Zschr. Instrumk. 15. pp. 313–322, 1895.)—A short description is here given of the building, in Berlin, in which the Imperial Commission of Standards carries out the comparison of lengths. Special care has been directed to the regulation of temperature; with the result that the daily variation of air-temperature within the room does not exceed a few hundredths of a degree. To attain this, the walls and ceiling are provided with a 10-inch air-jacket, formed between two coverings of sheet-zinc. The first covering is in contact with the wall, and the second is separated from this by

bolts. Gas-burners are distributed within the air-space, and by regulation of the flames and ventilation the air-temperature within the room is continuously controlled. The floor has a substratum of glass which keeps out moisture. The mechanism for comparing lengths is of the construction in which the moving part is the measuring-apparatus, and the object to be measured is kept at rest. The range is from nothing to two metres. Three drawings form the principal part of the description. R. A.

---

702. *Viscosity and Conductivity of Amalgams.* **E. R. v. Schweidler.** (Wien. Ber. 104. 4. Part II*a*. pp. 273–280, 1895.)—The measurements of viscosity were made by Poiseuille's method, under the pressure of the liquids themselves, care being taken to avoid oxidation by covering the amalgam with a layer of acidulated water. The results are given in the form $\eta = \eta_0(1 + \alpha t + \beta t^2)$.

	η_{20}.	α.	β.	r_0.	$\partial r/\partial t$.
Hg pure	0·01579	−0·00325	+0·0000066	1·	+·000928
Cd 2·8 °/ₒ	0·01691	360	153	0·8294	873
Pb 1·0 °/ₒ	0·01627	365	187	0·9666	854
Zn 0·6 °/ₒ	0·01639	300	059	0·9308	950
Cu 0·5 °/ₒ	0·01620	302	025		

r_0 is the resistance at 0° compared with mercury. R. A. L.

---

703. *Van der Waals' Thermodynamic Theory of Capillarity.* **W. Sutherland.** (Zschr. phys. Chem. 17. pp. 536-538, 1895.) —On Laplace's theory, capillarity is due to discontinuity at the surface; to explain capillarity with continuity, van der Waals retains terms which Laplace rejects as insignificant (Abstract No. 147, p. 67). But the condition of discontinuity in Laplace's theory could be got over without his expression for capillarity disappearing, by the consideration of an exceedingly thin layer of liquid: hence the assumption of continuity does not in itself cause this expression to disappear. It is especially necessary, therefore, to define *continuity* with regard to variation of density; for the rate of change of density at the surface of the mercury in a barometer could scarcely be small enough for van der Waals' method to be applicable. Since the replacement of discrete molecules by continuous media, and therefore of summations by integrations, makes the mutual action between two parts of a fluid appear to be independent of the average distance between its molecules, this method of calculation is bad. R. E. B.

---

704. *Vibrationless Supports for Instruments.* **W. H. Julius.** (Wied. Ann. 56. pp. 151-160, 1895.)—In order to avoid the mechanical vibratory disturbances to which rigidly supported instruments are subject, it is proposed to suspend them from three equal wires, two or three metres in length. (The arrangement is similar to the well-known English method of using indiarubber-tube suspensions.) Three wires are attached to an overhead beam,

at the angular points of an equilateral triangle; they carry at their lower ends a triangular plate for the support of the instrument. The centre of gravity of the whole suspended system, including the instrument, is to be at the centre of the triangular plate; to provide for this, a rod is fixed vertically downwards from the middle point of the under side of the plate; and by sliding a weight upon this rod the centre of gravity can be brought to the required position. The arrangement does not seem to have been put to an adequate practical test. For damping the effects of air-currents, side-vanes are fixed to the plate; these dip vertically into dash-pots. Uljanin has suggested that such dash-pots may be filled with cotton-wool. R. A.

705. *Vibrationless Supports for Instruments.* **W. Einthoven.** (Wied. Ann. 56. pp. 161–166, 1895.)—The readings of a Lippmann's electrometer are greatly affected by mechanical vibrations. The difficulty is overcome by supporting the instruments upon iron plates floating on mercury. This method of eliminating vibration was previously used by Michelson and Morley for a somewhat different purpose, and is described in 'The American Journal of Science,' (3) 34. R. A.

706. *Determination of the Density of Gases.* **H. Moissan** and **H. Gautier.** (Ann. Chim. et Phys. 5. pp. 568–573, 1895.)—The authors proceed after Dumas' method of determining vapour-densities, weighing equal volumes of the gas and of air. The measuring-bulb, of 100 c.c. capacity, is provided above with a three-way cock, from which an almost capillary U-tube for drawing in the gas branches off, and ends below in a calibrated tube to which a rubber pipe is joined, connecting the bulb with a mercury basin. On the stem above the three-way cock fits a glass balloon, also provided with a three-way cock, so that, starting from above, we have: balloon, cock, joint, cock, bulb, rubber tube. The balloon is ten times filled with dry air and closed; the gas is drawn into the bulb by manipulating the mercury basin, and the bulb closed; the apparatus is then left standing overnight, to equalise the temperatures. Next day the balloon-cock is opened for an instant to reduce the air in it to the atmospheric pressure, and weighed against a similar flask. The balloon is then evaluated, the gas pressed into it, the pressure almost balanced by introducing dry air, and the balloon reweighed. If p is the difference in weight in grammes, v the volume of gas and air at $t°$, then the density x results from

$$p = v \,.\, 0{\cdot}001293(x-1) \,.\, \mathrm{H}/760(1+0{\cdot}00367\,t).$$

Tests have been made with O, CO_2, H, N—the former pure; the N obtained from air, deprived of its CO_2 and then of its O by means of phosphorus. Hydrogen gave 0·068, 0·066, Regnault

0·069; Oxygen 1·100, 1·101, Regnault 1·1056; Nitrogen 0·979, 0·980, Regnault 0·9714. The method seems, therefore, sufficiently accurate for laboratory purposes. H. B.

707. *Critical State.* **K. Wesendonck.** (Wied. Ann. 55. pp. 577–581, 1895.)—Further discussion (*vide* Abstract No. 334), ntroducing the experiments of Villari (Journ. de Phys. (3) 3. p. 441, 1894), as to whether the critical change occurs at a definite emperature or through a small interval of temperature. S. S.

708. *Solubility of Hydrated Mixed Crystals.* **W. Stortenbeker.** (Zschr. phys. Chem. 17. pp. 643–650, 1895.)—The paper contains a graphical representation of the solubility-isothermals for two isomorphous substances which form (A) two sorts of mixed crystals and (B) three sorts. S. S.

709. *Organic Developers of the Latent Photographic Image.* **A.** and **L. Lumière.** (Ann. Chim. et Phys. 4. pp. 271–288, 1895.)—The authors have endeavoured to determine some general characteristics in the chemical constitution of those organic reducing agents which possess the power of developing the latent image. The experiments were mostly on members of the aromatic group. A substance of this series, to be a developer, must possess at least two radicals OH or two NH_2, or one OH and one NH_2. These radicals, too, must be in positions either para or ortho. The developing power is greatest in position para, less in ortho, and *nil* in position meta. Thus, of the three isomers resorcinol, pyrocatechin, and hydroquinone, which are respectively meta-, ortho-, and para-hydroxybenzene, the latter two are good developers, while the first has no effect. In the case of a double ring, the foregoing conditions must be fulfilled by radicals in the same ring. The developing power is not lost on making further substitutions in the other CH radicals, though the presence of COOH makes the use of a strong alkali necessary in development. Bodies not containing this group will develop in neutral or even acid solutions, provided they possess more than two substitutions OH or NH_2. Substitution in the hydroxyl and amide groups destroys the developing power. No other groups besides the three $HO—OH$, $HO—NH_2$. $H_2N—NH_2$ confer developing power on members of the aromatic series, and these give no result in the fatty series. The latter two, hydroxylamine and hydrazine, themselves are developers. Several compounds —resorcinol, guaiacol, and others—which have been considered as developers were found to give no result when pure. G. H. Ba.

710. *Electrical Conductivity of Palladium-Hydrogen in Relation to its Dissociation Pressure.* **A. Krakau.** (Zschr. phys. Chem. 17. pp. 689–704, 1895.)—A palladium wire is saturated with hydrogen

in a voltameter containing dilute sulphuric acid. The quantity of hydrogen is estimated by a second voltameter with platinum plates in series with the first. After some time the connection is broken, and the resistance of the wire is measured by a Wheatstone's bridge. The following are the conclusions :—

(1) For the formation of Pd_2H the presence is required of a volume of hydrogen greater than 40 times that of the palladium. The influence of temperatures up to 140° on this ratio is not great.

(2) Up to 40 volumes the hydrogen is simply dissolved in the palladium, and the vapour-pressure is proportional to the volume dissolved.

(3) The electrical resistance increases at various rates according as the hydrogen is only dissolved or exists as a chemical combination. S. S.

LIGHT.

711. *Absorption-Spectrum of Water, and the Tissues of the Eye.* **E. Aschkinass.** (Wied. Ann. 55, pp. 401–431, 1895.)—Experiments were made chiefly on the infra-red rays. The instrument used was a bolometer of customary construction, having a sensitiveness of one scale-division for 3×10^{-5} degree Cent. Layers of water were used, either 0·001 cm. thick (between two fluorite plates separated by a ring of tin-foil) for the range $\lambda = 1·64\ \mu$ to $8·49\ \mu$; 0·005 cm. ($\lambda = 0·670$ to 2·711); 1 cm. ($\lambda = 0·705$ to 1·450); 5 cm. ($\lambda = 0·670$ to 1·205), or 100 cm. ($\lambda = 0·45$ to 0·8). In the first case a fluorite prism was used; in the others flint glass; and in the last case a larger spectroscope and more delicate bolometer were required. The maxima of absorption at $6·10\ \mu$, $4·70\ \mu$, $3·06\ \mu$, $1·94\ \mu$, $1·50\ \mu$, $1·25\ \mu$, $1·00\ \mu$, $0·77\ \mu$ found agree with those observed by Paschen and others. A table is calculated giving the absorption-coefficient ϵ for all the wave-lengths, ϵ being the reciprocal of the thickness required to reduce the intensity of the radiation in the ratio $e:1$. It increases from 0·00005 at $\lambda = 0·5375\ \mu$ to 2733 at $\lambda = 3·02\ \mu$. At the limit of the red it has the value 0·0241.

In the second part of the memoir similar experiments on the tissues of the eye are described. The author failed to find any appreciable difference between them and water. He concludes, accordingly, that the invisibility of the rays below $0·76\ \mu$ is not due to absorption in the eye, the absorption being, in fact, only 35 per cent. at $\lambda = 1·095\ \mu$. R. A. L.

712. *Lighting by means of Incandescent Gases.* **C. E. Guillaume.** (L'Ind. El. 4. p. 378, 1895.)—This is a letter written by Guillaume to Hospitalier criticising a paper by A. Wirtz in C. R. 121. pp. 306–308, 1895. Guillaume declares Wirtz to be wrong in considering the absorption of the rays from the invisible part of the spectrum by different liquids to be the same, and notes that the experiments of Zsigmondi have shown that solutions of certain iron salts are much more absorbent than pure water, even when they are colourless. The details of the calorimeter used by Wirtz are not given, and consequently the value of his results cannot be estimated. In exciting his vacuum-tubes, Wirtz used an induction-coil and a Holtz machine. In the first instance power is measured by the products of volts and amperes, and in the second case by the difference of the powers required to drive the machine with and without the tubes. Guillaume objects to both of these methods of measuring power, because in the case of the induction-coil it is not stated whether the voltage is the maximum, the virtual, or the mean value, and in the case of the Holtz machine it is probable that the power necessary to overcome friction is not the same when the machine is working on open and on closed circuit. W. G. R.

HEAT.

713. *Calculation of the Heat of Solution from the Solubility.* **J. J. van Laar.** (Zschr. phys. Chem. 17. pp. 545–549, 1895.)—It is shown, both from the results of a previous paper (Abstract No. 692) and directly, that Rudolphi's formula $L = W + Q\alpha$ should be

$$L = W + Q\alpha/(2-\alpha),$$

where L is the actual heat of solution, W the heat of solution for undissociated salt, α the degree of dissociation, the concentration of the salt in a saturated solution being taken to be very small.

This result gives for L the value

$$L = \frac{4\tau^2}{2-\alpha}\frac{d}{d\tau} . \log C,$$

which is acknowledged as correct by van't Hoff, who, writing $i = 1 + \alpha$, has previously given both

$$2i\tau^2(d/d\tau) \log C \quad \text{and} \quad 2i\tau^2(d/d\tau) \log iC$$

for this value, the latter of which would also result from Rudolphi's incorrect formula.

Another of Rudolphi's formulæ is stated to be a particular case of one of the author's; but in the comparison the difference of a sign and the omission of a coefficient have been overlooked.

R. E. B.

---

714. *Critical Temperature and Boiling-Point of Hydrogen.* **K. Olszewski.** (Wied. Ann. 56. pp. 133–143, 1895.)—These temperatures were obtained by the expansion method used previously for finding the critical pressure. During a slow expansion from a high pressure to the critical pressure (20 atmospheres), the critical temperature is that indicated at the moment of first ebullition, and the temperature of the liquid attained on further expanding to ordinary pressure is the boiling-point. The main difficulty lies in fixing the exact temperatures. Thermo-couples are unsuitable for this purpose, being neither light nor sensitive enough. The author used a coil of platinum wire 0·025 mm. thick, mounted on a mica or ebonite support, which was introduced into a steel cylinder placed in communication with a hydrogen reservoir under 170 atmospheres. The varying resistance of the platinum coil served to measure the temperature, care being taken to make the current so small as not to heat the wire. The resistance of the coil at 0° C. was 104·9 ohms. The mica carrier and wire weighed only 0·177 grammes. To calibrate the resistance-thermometer, the steel cylinder was immersed successively in melting ice, a mixture of ether and solid carbonic acid, in liquid oxygen at atmospheric pressure, and in the same under a pressure of 15 mm.: the tempe-

ratures of 0°, −78°·2, −182°·5, and −208°·5 being indicated by the hydrogen thermometer in the four cases. Assuming the platinum to have a resistance of 1000 ohms at 0° C., this would fall to 523 ohms at −182°·5, and to 453 at −208°·5. Between these two temperatures, therefore, a difference of resistance of 2·692 ohms corresponds to 1° C. difference of temperature. Three different platinum coils were used, which all showed the same temperature-coefficient. Reducing the resistance in each case to 1000 ohms at 0°, the following indications were obtained:—

H expanded to	Resistance.	Temperature.
20 atm. (critical pressure)..	383 ohms	−234°·5 (critical temperature)
10 „	369 „	−239°·7
1 „	359 „	−243°·5 (boiling-point)

These values, −234°·5 for the critical temperature and −243°·5 for the boiling-point, differ only slightly from the values predicted by Natanson from thermodynamic considerations. E. E. F.

SOUND.

715. *Resonance.* **Neyreneuf.** (Ann. Chim. et Phys. 5. pp. 418–428, 1895.)—A reed is mounted on a tube whose length can be varied, and air is blown in through a side tube. The reed can only be made to sound with certain lengths of resonance-tube, and the difference between any two of these lengths is a multiple of $\frac{1}{2}\lambda$. Experiments were made with a tube which, at the end farthest from the reed, expanded into a wide cylinder. In this case the movement of the reed depends only on the length of the narrower tube, except when the wider tube is of such a length as to produce resonance. If the cylinder is altered in length by allowing water to flow in or out, in general the action of the reed is not affected by the position of the water-level, but when the level is in certain small regions $\frac{1}{2}\lambda$ apart, the reed becomes very sensitive to small changes. If the expansion is not cylindrical, similar phenomena are observed, but the sensitive regions are not equidistant. When the expanded space is made heterogeneous by being filled with shot, coke, metal turnings, &c., the results are the same, but the wave-length is diminished. According to the author's measurements, when the water-level is rising the wave-length observed is a little less than the normal wave-length of the sound, and *vice versa.* J. W. C.

716. *Siren.* **H. Pellat.** (J. Phys. 4. pp. 366–368, 1895.)—This siren is one of the type provided with a separate motive power. The disc is driven by an electric motor mounted on its axle, and fed with a current of 3 or 4 accumulators. The holes in the disc are bored perpendicular to the fan of the disc, instead of slanting as in Cagniard de la Tour's siren. Hence the air passing through does not affect the velocity of the disc, and any degree of loudness can be given to the same note. The pitch is regulated by an electric brake in the shape of a copper disc mounted on the axle, and rotating between two powerful electromagnets supplied by a branch of the same circuit in which a rheostat is inserted. The most striking difference between this and the ordinary siren lies in the low notes, which can be given a great intensity and have then as pleasing a musical character as high notes. E. E. F.

ELECTRICITY.

717. *Electrical Conductivity of Salts in various Solvents.* **C. Cattaneo.** (Rend. Ac. Linc 4. 2. pp. 63-70, 1895.)—The author adds to those he has already published, data for HgI_2, $AuCl_3$, and $PtCl_4$ dissolved in various solvents, *i. e.*, water, alcohols, and ethyl ether, and he promises the full discussion of the numeral results in a further communication. S. S.

718. *Fall of Potential in a Three-Phase Circuit.* **J. Rodet.** (L'Ind. El. 4. pp. 402–405, 1895.)—This paper is devoted to the calculation of the fall of potential in the various sections of a triphase circuit arranged in the mesh fashion. Particular cases are considered according to the way in which the load is distributed amongst the three sections. The particular cases considered are (1) one section only loaded; (2) two sections loaded; (3) a system in which motors are connected with all three sections of the line, but lamps between two of the sections only. The conclusion the author arrives at is that the fall of potential in the sections may be diminished, but at the cost of increased weight of copper.

W. G. R.

719. *Reverberatory Electric Furnaces.* **H. Moissan.** (Ann. Chim. et Phys. 4. pp. 365–390, 1895.)—In the Ecole de Pharmacie, Moissan had only a 4 H.P. gas motor; later on, the Gramme Co., and then the Edison Co., placed their power at his disposal, so that he could utilize up to 150 and 300 H.P. None but continuous currents were employed. Most of the furnaces consist of an upper and a lower block, the lower having two horizontal grooves in the same straight line, through which the electrodes are pushed, and a hollow in the centre. For the early and some special experiments quicklime, from the greenbank of the Paris basin, formed the block material. For currents of between 40 and 125 amperes and 55 or 60 volts, the lower block would be 18 × 15 cm., and 8 cm. thick, the upper 5 or 6 cm. thick; for greater currents, all dimensions are increased by 2 or 3 cm. The electrodes are made of retort-carbon, powdered, extracted with acids, calcined, mixed with tar, highly compressed, and again calcined; boric acid and silicates are particularly to be avoided; the original carbon must not contain more than 1 per cent. of ash. The electrodes are from 20 to 40 cm. long, and from 12 to 27 mm. (and even 50 mm.) in diameter. When working with currents of less pressure, both electrodes should be pointed conically, as it is awkward to restart the arc; for larger currents, one electrode may be left plane. When the furnace has become quite hot, the metallic vapours prevent any interruption of the arc. The

carbon crucibles, put in the hollow, on a bed of magnesia are cylindrical, 4 cm. high, 3 and 2 cm. in external and internal diameters, and are provided with grooves for the electrodes. When made of ordinary retort-carbon, they swell a good deal; when specially prepared from powdered carbon, they are also partly transformed into graphite, but retain their shape. There should be an annular space, 1 or 2 cm. wide, between the crucible and the walls of the hollow. The magnesia-bed is required, as at the high temperature the lime is reduced, a calcium-acetylene compound being formed. When lime is to be volatilised from and in the furnace, a hollow of 3 cm. depth is scooped in the lower block; no crucible is needed. After 4 minutes, with currents of 360 amperes and 70 volts, flames 50 cm. long burst through the grooves, and clouds of lime-fumes fill the room, where they remain suspended for hours. Currents of 800 amperes and 110 volts will volatilise 100 gr. of CaO in 5 minutes. As soon as the arc is struck, the odour of hydrocyanic acid, synthetised from the water in the carbons, acetylene and the nitrogen of the air (Berthelot), and the purple cyanogen flame become noticeable. This soon stops, and the arc of 1 cm. has to be lengthened to 2 cm. more; when metallic vapours (Al) are present, arcs of 5 or 6 cm. have to be used. The lime may form waxy stalactites. It conducts the heat so badly that the still radiating cover may be held in the hand. In this respect lime is far superior to magnesia, which, though irreducible so far, does not allow the heat to be so well concentrated. With carbon furnaces, the losses of heat are far greater still. The positive carbon electrode suffers less than the negative; both are converted into graphite over lengths of 8 or 10 cm. With strong currents shunt circuits may form, and the apparatus has to be handled with great care. The arc-flashes endanger the eyes more with weaker currents, because the experimenter is less hampered by the heat and attempts to observe more closely.

Limestone furnaces are, on the whole, more easily made. For 100 H.P. the dimensions are: lower block 30 × 20 cm., 15 cm. thick; upper block, 11 cm. thick; such a furnace can bear 6 or 8 operations. The bed should consist of alternate layers of magnesia and carbon, the crucible standing on magnesia. The stone has to be dried carefully; to obviate any splitting, the blocks are clasped by iron bands. The carbonic acid generated is reduced to carbonic oxide which, in spite of all ventilation, sometimes disabled the experimenter for weeks. When vapours are to be condensed, a copper **U**-tube 15 mm. in diameter is introduced, through which a water-current is forced under a pressure of 10 atm.; the temperature is said not to rise by more than 3°. For the maximum power of 300 H.P., carbons 5 cm. in diameter are employed; they are wound at their ends with wire-gauze and held by stout copper jaws. The crucibles had 7·5 and 9 cm. (inside and outside) in diameter, a height of 10 cm., and could yield 400 gr. of fused tungsten in 6 minutes. Magnesia crucibles have also been employed. The magnesia is prepared by Schloesing's method from calcined bicarbonate, several times washed, calcined again, and finally stirred with water to form bricks which must be dried very slowly, before they can be baked. As the most intense arcs of 1400 amperes and 100 volts melt the lime which drops, giving rise to crepitations and violent fuming, the walls of the wide, right-angled chamber are lined with alternating plates of magnesia 0·01 m. in thickness, and of carbon. The magnesia melts and evaporates; the heat further renders it more dense, the specific gravity rising from 3·193 to 3·654, which Ditte has ascribed to polymerisation.

When the gases of the furnace are to be excluded, carbon tubes, from 5 to 40 mm. in internal diameter, are inserted in the wide chamber, below the electrodes, which they cross at right angles. When the tube is above the arc ["dessus" is printed in both instances, here as in other places] the temperature cannot be raised so high. These tubes are porous, so that any gases, hydrogen or nitrogen, have to be forced through at a rapid rate. All attempts to prepare a suitable carbide coating have failed, but magnesia and double tubes have been used with some success. For metallurgical tests, these tubes are inclined under 30°. The mixture is continuously charged in at the one end; the metal runs out at the other end, still within the furnace, and is further fused by another arc. Up to 10 kg. of chromium have been fused in one operation. The temperature seems to increase with the current, and probably rises to 3500°.

H. B.

720. *Holtz Influence Machine.* **K. E. F. Schmidt** and **H. Rühlmann.** (Wied. Ann. 56. pp. 167–170, 1895.)—The attempt was made to increase the output of the Holtz machine by simply increasing the speed, the size of the armatures, and the number of teeth in the collecting combs. The current supplied by the machine under various conditions was measured by a galvanometer, the influence-machine being driven at various speeds by an electric motor. In every case the current was directly proportional to the speed of rotation. On increasing the radial breadth of the armatures from 10 to 14·5 cm., and the number of teeth in the combs from 14 to 31 (in two rows), the output was increased by nearly 20 per cent., the speed being the same. When the humidity of the air decreased from 3·2 to 2·1, the output was further increased by 25 per cent. In a Toepler machine of the same dimensions, the increase of efficiency due to similar constructive alterations was only 6 per cent., and the current was not so steady as in the Holtz. The duplication of the comb-teeth also makes the current decidedly steadier.

E. E. F.

721. *Magnetic State of the Planets.* **E. Leyst.** (Repertorium für Meteorologie, 17. 1, pp. 1–118, 1894.)—The author has exhaustively examined the photographic records of the magnetographs at St. Petersburg, and later at Pawlowsk between 1873 and 1889, to see if it is possible to trace any systematic effect produced

on the terrestrial magnetic elements by the other planets of the solar system. In this paper the author deals at great length with the declination records, and somewhat less fully with those of horizontal force. Three methods are employed :—(1st) The mean declination for the day at which the inferior or superior conjunction in the case of the inferior planets, or conjunction or opposite in the case of superior planets, takes place is compared with the mean declination for neighbouring days or for the month. (2nd) By means of the mean value of the secular change for the period 1873–1885 the value of the declination for the time of conjunction, &c. is compared with the actual value. (3rd) The value of the diurnal range at conjunction, &c. is compared with the mean value. Although the differences obtained are excessively small, amounting as they do to only a fraction of a minute of arc, and large as is the probable error, the author considers that the numbers obtained point to the planets being so highly magnetised that they are capable of affecting the magnetism of the earth to an extent which is recognisable with the magnetographs now in use. W. W.

722. *Conductivity of Mixtures of Metallic Filings and Dielectrics.* **G. T. Lhuillier.** (C. R. 121. pp. 345–348, 1895.) —Experiments are first adduced to show that the increase in conductivity, which is produced by an induced E.M.F. in tubes containing mixtures of filings and various dielectrics, is not due to a modification of the dielectric as a whole, for a liquid dielectric can be removed and replaced by another without disturbing the altered conductivity. The liquids for this must possess no interaction, *e. g.*, water can replace olive oil. Further, it is shown that the increase of conductivity does not result from a modification of a liquid sheath adhering to each metallic particle, by means of direct experiment made with a point and plane which could be approached very close together. The effect is attributed principally to a drawing into contact of the metallic particles. F. T. T.

723. *Sources of Error in very Sensitive Apparatus.* **H. Armagnat.** (L'Ind. El. 4. pp. 380–382, 1895.)—The author considers the errors introduced into readings with a very sensitive galvanometer due to the gravitational attraction of the needle by the coils of the instrument, and finds that the error is of the same order of magnitude as the quantities to be measured. Experiments are made with a Weiss astatic galvanometer recently presented to the Société française de Physique. The galvanometer consists of two pairs of very small coils between which are suspended two magnetic needles and separated by distance of 0·06 cm.; the magnets weigh 5 milligrammes each, and are mounted on a strip of mica.

Let M, M' be the magnetic moments of the two needles;
H the intensity of the field in which the instrument is placed;
n the number of turns of wire on a pair of coils;

ρ the mean radius of the coils; and
C the figure of merit of the galvanometer.
Then, if the needles are deflected through an angle α, we have

$$H(M-M')\sin\alpha=2M\frac{2\pi n}{\rho}\cdot\frac{1}{C}\cos\alpha.$$

In the Weiss galvanometer the directing couple is given by

$$H(M-M')=\frac{730\times10^{-10}}{C}\text{ ergs,}$$

C being expressed in megohms.

The author proceeds to calculate roughly the Newtonian attractions in this galvanometer, and finds that moment of the couple due to these forces is approximately

$$\frac{2Km\mu D\delta^2\sin\alpha\cos\alpha}{\left(\frac{D^2}{4}-\delta^2\sin^2\alpha\right)^2},$$

where m is the mass of the magnets, μ that of the coils; D the distance between the coils; 2δ the distance between the needles; K the gravitational constant; and α the angle through which the needles are turned.

When this couple is equal to the couple

$$H(M-M')\sin\alpha,$$

the galvanometer-needles are in unstable equilibrium.

In the galvanometer in question,

$$D=0\cdot5\text{ cm.},\quad \delta=0\cdot06\text{ cm.},$$
$$m=0\cdot01\text{ gm.},\quad \mu=5\text{ gm.};$$

so that when the equilibrium is unstable, we have, neglecting $\delta\sin\alpha$ in comparison with D, and putting $\cos\alpha=1$,

$$H(M-M')=\frac{32Km\mu\delta^2}{D^3}$$
$$=\frac{71}{10^{10}};$$

and the value of C is then given by

$$\frac{730\times10^{-10}}{C}=\frac{71}{10^{10}},$$

or

$$C=\frac{730}{71}=10\text{ megohms (nearly).}$$

In reality much greater sensibilities can be obtained since the suspension is acted on by a force which is the difference between the magnetic force and the Newtonian attraction. A figure of merit of 800 megohms has been reached without being troubled by changes of zero, but the above calculation shows that the Newtonian attractions are of the same order of magnitude as the magnetic forces, and therefore must be taken into account when constructing very sensitive apparatus of small dimensions.—The numbers given above are not all as given by the author, the paper containing several arithmetical errors. W. G. R.

---

724. *Electric Discharge in Gases.* **O. Lehmann.** (Wied. Ann. 55. pp. 361–388, 1895.)—The author investigates the circumstances attending the arc and the low pressure gas-discharge. In order to avoid interference from the walls of the containing vessel, this vessel consists of a large glass receiver 40 cm. wide and 50 cm. high. Under certain circumstances the arc begins and ends at bright points on the electrodes, and in this case there is a brush of metallic vapour proceeding from each electrode. By comparing the length of brush from an iron electrode when it proceeds with and against the convection-currents, the author estimates the velocity of diffusion of the iron vapour at ·14 m. per sec., which is probably much greater than the ordinary diffusion velocity. Hence he concludes that the vapour is ejected by electrical forces. He thinks that the presence or absence of the metallic brush is the essential difference between the arc and the gas-discharge. The axial discharge is surrounded by a bright, sharply bounded aureole. Experiments were made to find whether this aureole is due to the presence of stream-lines, or is a chemical or fluorescence effect. A magnet deflects it as though it consisted of a bundle of stream-lines. Non-conducting obstacles cause it to be deformed but cast no shadow. A thermometer shows almost no rise of temperature outside the aureole, but rises at once to 400° or higher as soon as it touches the outer limit of the aureole. Hence the aureole is probably made up of stream-lines, and there are none outside it. The author discusses the nature of striæ, and concludes that they are due to partial discharges across well and badly conducting layers, and hence are perpendicular to the lines of flow of energy. The paper is accompanied by numerous figures of discharges, stream-lines, striæ, &c. J. W. C.

---

725. *Electrolytic Conductivity of Concentrated Sulphuric Acid.* **K. E. Guthe** and **L. J. Briggs.** (Phys. Rev. 3. pp. 141–151, 1895.)—Both the specific and molecular conductivities of sulphuric acid have a minimum which becomes less pronounced at higher temperatures, at a concentration which closely corresponds to the hydrate $H_2SO_4+H_2O$. The authors have investigated this more carefully than has hitherto been done, the measurements being made by a method similar to the well-known one of Kohlrausch, the alternating current being supplied by a small dynamo of special design, and the telephone replaced by a sensitive dynamometer. Measurements are made on solutions containing from 73·88–97 per cent. of H_2SO_4, at temperatures between 0° and 30° C. The following numbers are interpolated from the actual

measurements. The numbers under molecular volume are the volumes in c.cm. which contained a gram-equivalent of H_2SO_4 ($=\frac{1}{2}H_2SO_4$). α is the temperature-coefficient of the solution, and is obtained from the formula

$$\mu_x=\mu_{18}\{1+\alpha(t_x-t_{18})+\beta(t_x-t_{18})^2\}.$$

0°.		10°.		18°.		25°.		
Mol. vol.	Mol. cond. μ $\times 10^{-12}$.	Mol. vol.	Mol. cond. μ $\times 10^{-12}$.	Mol. vol.	Mol. cond. μ $\times 10^{-12}$.	Mol. vol.	Mol. cond. μ $\times 10^{-12}$.	α.
27·25	1·66	27·39	2·29	27·50	2·88	27·59	3·46	0·0271
28·52	1·80	28·67	2·48	28·78	3·14	28·88	3·83	0·0291
29·30	1·78	29·46	2·50	29·57	3·19	29·67	3·88	0·0294
30·31	1·69	30·48	2·44	30·60	3·15	30·72	3·90	0·0315
31·26	1·61	31·43	2·39	31·58	3·14	31·67	3·92	0·0326
31·71	1·58	31·89	2·33	32·03	3·12	32·14	3·90	0·0338
32·34	1·56	32·50	2·35	32·65	3·14	32·77	3·97	0·0346
34·60	2·02	34·78	2·87	34·93	3·77	35·06	4·68	0·0321
36·02	2·46	36·21	3·49	36·36	4·51	36·49	5·47	0·0295
37·80	3·08	38·00	4·21	38·16	5·37	38·31	6·51	0·0290
39·57	3·82	39·79	5·14	39·97	6·47	40·11	7·77	0·0273

μ appears to be expressed in reciprocal ohms.

The numbers show that the minimum conductivity occurs at a mol. vol. of 32·1, independent of the temperature, and that, as Kohlrausch has already observed, the larger the conductivity the smaller is the temperature-coefficient.

The conductivity of the solid hydrate $H_2SO_4+H_2O$ is also investigated, and found to remain unchanged by recrystallization under varying conditions. It is therefore probably not due to enclosed mother liquor. It increases very rapidly with rising temperature, but, as the following numbers show, it has at the melting-point of the solid hydrate, viz. 7°·5, a considerably smaller value than that of the liquid at the same temperature.

Solid Hydrate, $H_2SO_4 . H_2O$.		Liquid Hydrate, $H_2SO_4 . H_2O$.	
Temperature.	Specific conductivity.	Temperature.	Specific conductivity.
−20°·0	$0·846\times 10^{-12}$		
−15·0	1·147		
− 8·0	1·755		
0·0	3·47	0°·0	$48·61\times 10^{-12}$
5·0	8·06	4·8	59·12
7·2	18·78		
7·5	28·44		
		9·5	70·74
		11·0	75·63

T. E.

726. *Distribution and the Secular Variation of Terrestrial Magnetism.* (I.) **L. A. Bauer.** (Am. J. Sc. 50. pp. 109–115, 1895.)—The paper is devoted to further substantiate the conclusion previously drawn by the author, that the two phenomena, the distribution and secular variation, appear to be closely related; they obey similar laws, and seem to be connected in some way with the rotation of the earth. In the present paper the declination and dip are alone discussed. The conclusions drawn are:—(I.) The mean declination along a parallel of latitude is always westerly, the minimum occurring near the equator; the quantities, in general, increase upon leaving the equator. (II.) The mean inclination along a parallel of latitude follows quite closely the law

$$\tan I = 2 \tan \varphi,$$

I being the dip and φ the latitude. (III.) The minimum range in declination along a parallel of latitude occurs near the equator, generally increasing upon leaving the equator. (IV.) The maximum range in dip along a parallel of latitude occurs near the equator, generally diminishing upon leaving the equator. (V.) The minimum average secular change in declination along a parallel of latitude from 1780 to 1885 occurred near the equator, the values generally increasing upon leaving the equator. (VI.) The maximum average secular change in dip along a parallel of latitude from 1780 to 1885 occurred near the equator, the values generally diminishing upon leaving the equator. W. W.

727. *Compounding Dynamos for Armature Reaction.* **E. Thomson.** (T. Am. Inst. El. Eng. 12. pp. 394–403, 1895.)—The object of this paper is not to bring forward any method which the author considers at present fit to introduce for neutralising armature-reaction in direct-current dynamos, but to show the possibility for the armature-current to neutralise its own effects in a proper structure and maintain, or even increase, the potential at the brushes under a heavy load. The result is accomplished by winding only alternate poles in a multipolar machine, the others remaining "dead" poles, being excited by the armature-current only. Details of such a machine are given, and the results of an experimental investigation of the variation of the difference of potential at the brushes. The results are extremely satisfactory; though, as the author remarks, the machine described is chiefly interesting from its theoretical aspect. The object is attained inasmuch as armature-reaction does not cause a drop of potential at the terminals of the machine, but the cost per horse-power is increased.
W. G. R.

728. *Double Refraction of Electric Radiation.* **P. Lebedew.** (Wied. Ann. 56. pp. 1–17, 1895.)—The author has obtained the phenomena of double refraction of electric radiation in a natural *crystal*, the wave-length used being 6 mm. The oscillator consisted

of two platinum cylinders, each 1·3 mm. long and 0·5 mm. diameter. These were fused into the tips of glass tubes and charged by wires from within them, connected to an induction-coil giving 30 interruptions per second. The oscillator was placed in the focal line of a cylindrical mirror of circular cross section, 2 cm. high, 1·2 cm. wide, and 0·6 cm. focal length. The spark-gap between the two parts of the oscillator was 0·02 mm., the sparks passing in petroleum in which the oscillator and mirror were both completely immersed. The beam of electric radiation passed out of this bath through a mica window. A second cylindrical mirror of parabolic section, 2 cm. high, 1·2 cm. wide, and 0·14 mm. focal length, served to concentrate the radiation upon the resonator. This consisted of two straight conductors, each 3 cm. long. At the inner ends of these one junction of a thermo-electric couple was placed, the whole resonator and mirror being inclosed in a screen to protect the junction from air-currents. The radiation incident upon the resonator is estimated by the first throw of a galvanometer connected with the thermo-electric couple. This galvanometer gives a deflection of one scale-division for a current of 6×10^{-9} amperes, and, to avoid external magnetic disturbances, is inclosed in an iron screen 2 cm. thick. Both mirrors stand upon a spectrometer: the focal line of that containing the oscillator is fixed vertical, while the mirror for the resonator is carried by an arm and is capable of rotation about the electric beam as axis. The distance between the two mirrors was usually 10 cm., and the galvanometer-throws then obtainable ranged from 20 to 30 scale-divisions. With this apparatus Hertz's fundamental experiments were readily repeated. For polarisation phenomena a 2 cm. square grating of 20 thin wires was used, the behaviour of such gratings with the focal lines of the mirrors parallel and crossed being identical with that observed by Hertz. The wave-length of the electric radiation was easily obtained by Boltzmann's method, in which two plane mirrors are used to produce interference-phenomena. A maximum, a well-defined minimum, and again a feebly-marked maximum were obtained with differences of paths of 0 mm., 2–3 mm., and 5–6 mm. respectively. With greater differences of path no further periodic fluctuations were observable, a proof that the oscillations under examination were strongly damped. According to these observations the wave-length was taken to be $\lambda = 6$ mm., which agrees with the value obtained by measurement of the apparatus. The transparency to this electric radiation of insulators (ebonite, mica, and glass) and the opacity of metallic conductors were also verified. For reflection, a plane metallic mirror 2 cm. square was found suitable. In order to demonstrate refraction, the author used an ebonite prism 1·8 cm. high, 1·2 cm. wide, and with a refracting angle of 45° and weighing barely 2 gm., whereas that used by Hertz weighed about 600 kgm. The prism was set up on the spectrometer-table, distant 3 cm. from the primary mirror and 7 cm. from that of the resonator, the readings being taken, as usual in optics, for the two positions of minimum deviation. To obtain the exact position of the deviated ray after passing through the prism, galvanometer-throws are taken with the resonator in various positions along the graduated circle of the spectrometer. A curve is then plotted with angular positions of resonator as abscissæ and galvanometer-throws as ordinates. From this curve the position of maximum throw can be determined within about 3°. The refractive index of ebonite was thus determined to be $n = 1{\cdot}6$. The square roots of the various determinations of the dielectric constant for ebonite vary between 1·4 and 1·8, thus agreeing, within the errors of observation, with Maxwell's Law. The smallness of the waves here used made it possible to carry out the fundamental optical experiments with crystalline media. For this purpose the *natural rhombic sulphur* was specially suitable both on account of its high insulation and the marked difference between its two indices of refraction. The determinations of these from the minimum deviations produced by prisms of the crystal gave

$$n_1 = 2{\cdot}2 \quad \text{and} \quad n_2 = 2{\cdot}0.$$

These again agree well with the square roots of the dielectric constants as determined by Boltzmann, viz.,

$$\sqrt{4{\cdot}77} = 2{\cdot}18 \quad \text{and} \quad \sqrt{3{\cdot}81} = 1{\cdot}95.$$

The electrical analogue to a Nicol's prism was then constructed as follows :—A parallelopiped of crystalline sulphur, 2 cm. by 1·8 cm. by 1·2 cm., with its edges parallel to the dielectric axes, was cut into two parts, and between them a plane ebonite plate, 1·8 mm. thick, introduced. The electric radiation incident upon this prism was divided into two components, one of which suffered total reflection at the ebonite plate and emerged sideways, while the other component was freely transmitted. With this "Nicol" the usual optical phenomena were obtained. A quarter-wave plate for the electric radiation $\lambda = 6$ mm. was also made of sulphur crystal, its dimensions being 2 cm. square and 6 mm. thick. With this plate circular polarisation and the other ordinary optical effects were readily reproduced. E. H. B.

729. *Phasing Transformers.* **C. S. Bradley.** (T. Am. Inst. El. Eng. 12. pp. 494–506, 1895.)—The author gives the name "phasing transformer" to an arrangement of transformers, condensers, etc., by means of which a three-phase current can be obtained from a single-phase generator. The object in view is to show that there is not any need to change the nature of a single-phase plant at a central station in order to use tri-phase induction-motors. The arrangement consists of two primary coils—one a simple coil, and the other a compound one containing a capacity. The two primaries are placed in series with each other and with a single-phase generator. To the simple primary coil correspond three secondary circuits, and to the compound primary two secondaries. Naming these circuits *a*, *b*, *c*, *d*, *e*, one phase is obtained from

a and e, another from b and d, and a third from c. By a proper adjustment of the ratio of the capacity and the self-induction, the three currents may be made to differ in phase by any desired amount. W. G. R.

730. *Magnetism of Iron Cylinders.* **Ascoli.** (Rend. Acc. Linc. 4. 1, pp. 341–346, 1895.)—The author discusses the objections raised by Grotrian to the observations recorded in previous papers (see Abstracts Nos. 321 and 327). W. W.

731. *Secular Motion of a Free Magnetic Needle.* **L. A. Bauer.** (Phys. Rev. 2. pp. 455–465, 1895, and 3. pp. 34–48, 1895.)—This is a paper, in English, dealing with the same subject as that referred to in Abstract No. 248. W. W.

732. *General Alternate-Current Transformer.* **C. P. Steinmetz.** (T. Am. Inst. El. Eng. 12. pp. 351–365, 1895.)—The author defines a *general alternate-current transformer* to be any electromagnetic apparatus which consists of a magnetic circuit interlinked with two electric circuits—one, the primary circuit, being excited by an impressed E.M.F., while in the other, the secondary circuit, an E.M.F. is induced. The above definition obviously includes both the ordinary alternating-current transformer and the induction-motor. In the general alternating-current transformer, therefore, changes may take place in E.M.F., current, and also in frequency, since the secondary circuit may be either stationary or movable.

Let k = ratio of secondary frequency to primary frequency, or the "slip."
,, n_0 = number of primary turns in series per circuit.
,, n_1 = number of secondary turns in series per circuit.
,, $a = n_0/n_1$ = ratio of turns.
,, $Y_0 = \rho_0 + j\sigma_0$ = primary admittance per circuit, where
ρ_0 = effective conductance = ratio of hysteretic energy-current to E.M.F.,
σ_0 = susceptance = ratio of magnetising current to E.M.F.,
j = the imaginary $\sqrt{-1}$, with its usual interpretation.
,, $U_0 = r_0 - js_0$ = internal primary impedance per circuit, where
r_0 = effective resistance of primary circuit,
s_0 = reactance of primary circuit.
,, $U_1 = r_1 - jks_1$ = secondary impedance, where
s_1 = secondary reactance at standstill, and
r_1 = effective resistance of secondary coil.

Let the secondary circuit be closed by an external resistance r and an external reactance ks; so that

$$U = r - jks = \text{external secondary impedance.}$$

Let E_0 = primary impressed E.M.F. per circuit.
,, E_0' = E.M.F. consumed by primary counter E.M.F.
,, E_1 = secondary terminal E.M.F.
,, E_1' = secondary induced E.M.F.
,, e = E.M.F. induced per turn by the mutual magnetic flux, at full frequency.
,, C_0 = primary current.
,, C_{00} = primary exciting current.
,, C_1 = secondary current.

We then have

Secondary induced E.M.F. $= E_1' = kn_1e$,
Total secondary impedance $= U_1+U = (r_1+r)-jk(s_1+s)$;

therefore

$$C_1 = \frac{E_1'}{U_1+U} = \frac{kn_1e}{(r_1+r)-jk(s_1+s)}. \quad . \quad . \quad . \quad . \qquad (1)$$

Also

$$E_1 = E_1' - C_1U_1 = C_1U$$

$$= kn_1e\left\{1-\frac{r_1-jks_1}{(r_1+r)-jk(s_1+s)}\right\}$$

$$= \frac{kn_1e(r-jks)}{(r_1+r)-jk(s_1+s)}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (2)$$

Again,

$$E_0' = -n_0e;$$

therefore

$$C_{00} = E_0'Y_0 = -n_0e(\rho_0+j\sigma_0).$$

The component of the primary current corresponding to the secondary current, C_1, is given by

$$C_1' = -\frac{C_1}{a} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (3)$$

$$= -\frac{n_0ke}{a^2\{(r_1+r)-jk(s_1+s)\}};$$

therefore

$$C_0 = C_{00}+C_1$$

$$= -kn_0e\left\{\frac{1}{a^2}\,\frac{1}{(r_1+r)-jk(s_1+s)}+\frac{\rho_0+j\sigma_0}{k}\right\}. \qquad (4)$$

The primary impressed E.M.F.,

$$E_0 = E_0' + C_0U_0$$

$$= -n_0e\left\{1+\frac{k}{a^2}\cdot\frac{r_0-js_0}{(r_1+r)-jk(s_1+s)}+(r_0-js_0)(\rho_0+j\sigma_0)\right\}. \qquad (5)$$

From these we deduce that the ratio of the primary to secondary current is given by

$$\frac{C_0}{C_1} = -\frac{1}{a}\left\{1+\frac{a^2}{k}(\rho_0+j\sigma_0)\left[(r_1+r)-jk(s_1+s)\right]\right\}, \quad . \quad (6)$$

and the ratio of the E.M.F.'s is

$$\frac{E_0}{E_1} = -\frac{a}{k}\left\{\frac{1+\frac{k}{a^2}\cdot\frac{r_0-js_0}{(r_1+r)-jk(s_1+s)}+(r_0-js_0\rho)({}_0+j\sigma_0)}{1-\frac{r_1+jks_1}{(r_1+r)-jk(s_1+s)}}\right\}. \quad . \quad (7)$$

The total apparent primary impedance is given by

$$U_t = \frac{E_0}{C_0} = \frac{a^2}{k}\{(r_1+r)-jk(s_1+s)\}$$
$$\times\left\{\frac{1+\frac{k}{a^2}\frac{r_0-js_0}{(r_1+r)-jk(s_1+s)}+(r_0-js_0)(\rho_0+j\sigma_0)}{1+\frac{a^2}{k}(\rho_0+j\sigma_0)[(r_1+r)-jk(s_1+s)]}\right\}. . (8)$$

Equations (1) to (8) furnish a complete solution of the transformer problem, whether the secondary circuit is movable or stationary.

The general equations of the ordinary alternate-current transformer are obtained by putting $k=1$, and those of the induction-motor with short-circuited rotor by putting $U=0$.

The paper contains a discussion of these equations, and expressions are obtained for the input, output, and the various losses in the primary and secondary circuits. There are several misprints in the mathematical portions of the paper.

Equation (3) seems to require justification. We know that the magnetic flux in an induction motor is not constant; so that for equation (3) to be correct would require that C_{00} should be variable. It is not stated explicitly whether the currents and E.M.F.'s are mean, maximum, or virtual, and the nomenclature in general is very vague.
W. G. R.

---

733. *Magnetism of Volcanic Rocks.* **G. Folgheraiter.** (Rend. Acc. Linc. 4. 1, pp. 203–211, 1895.)—A number of specimens were examined by a rough magnetometric method—first, as found; secondly, after heating to 800°–1000° and cooling in the earth's field; thirdly, three months later. Most of the specimens were found to increase much in magnetisation by heating, and retain their magnetism afterwards. But "peperino" before heating possesses only temporary (induced) magnetism for the most part; after heating it becomes like tufa; and basaltic lava "con punti

distinti" possesses before heating much more magnetism than the earth's field is capable of producing, and therefore seems to owe its magnetisation to some stronger source. R. A. L.

734. *The Earth a Magnetic Shell.* **F. H. Bigelow.** (Am. J. Sc. 50. pp. 81–99, 1895.)—The author has, for some 30 stations at which hourly observations of the magnetic elements have been published, calculated the direction and magnitude of the vector representing the effect of the sun on the earth's magnetism. The results obtained incline the author to suppose that the earth consists of a hollow magnetic shell filled with a relatively magnetically impervious nucleus. The author also considers the action of the sun on various terrestrial meteorological phenomena.

W. W.

CHEMICAL PHYSICS.

735. *Effect of Centrifugal Force upon Chemical Systems.* **G. Bredig.** (Zschr. phys. Chem. 17. pp. 459–472, 1895.)—As far back as the beginning of this century an attempt was made by Gay-Lussac to discover whether a homogeneous vertical column of salt solution exhibited any change of concentration in the direction of its length under the action of gravity. He obtained a negative result; and it has since been shown, from thermodynamic considerations, that the changes of density which would be thus produced are so small as to be scarcely perceptible. Recently, Th. des Coudres has shown that similar effects should be produced by centrifugal force; and these are more suitable for experimental measurement. The author considers in detail the case of a rotating mixture of gases, and shows that if the system, immediately after the rotation, be divided into two parts by a plane perpendicular to a radius, the relative (and also the absolute) concentration of the gas which has the greater molecular weight will be greater in the outer than in the inner part. Thus it is possible to "centrifugally fractionate" a mixture of gases into its constituents. Experiments were made with a mixture of hydrogen and hydriodic-acid gas in a tube 16 cm. long, with a stopcock in the middle: this was rotated on a centrifugal machine making about 38 revolutions per second. It was found possible to separate the gases to the extent of about 3 per cent. Applications to heterogeneous systems (distillation of water, crystallisation, etc.) are also discussed. D. E. J.

736. *Amalgams of Iron.* **A. Zamboni.** (N. Cim. 4. 2, pp. 26–36, 1895.)—The author has prepared amalgams of iron by the electrolysis of an aqueous solution of ammonium ferrous sulphate, using an iron plate for the anode and a surface of mercury as the kathode. The amalgam obtained is strongly magnetic, more so than the black powder formed by its decomposition. If the magnetising or demagnetising force is slowly changed, it is found that the change in the magnetic state of the fluid amalgams is accelerated by tapping. With solid amalgams, however, this does not take place. The permanent magnetism which the amalgams are capable of retaining decreases with the increase of the mobility of the amalgam. W. W.

737. *Ostwald's Formula for Constants of Affinity.* **M. Rudolphi.** (Zschr. phys. Chem. 17. pp. 385–426, 1895.)—To express the effect of dilution on the conductivity of binary electrolytes, Ostwald gives the formula

$$k = \frac{(\lambda_v/\lambda_\infty)^2}{v(1-\lambda_v/\lambda_\infty)},$$

where k is a constant (the "coefficient of affinity"), v the volume of solution in which one gram-equivalent of the electrolyte is dissolved, and λ_v, λ_∞ the molecular conductivity at dilutions of v and infinity respectively. Although this expression holds good for a great number of weak acids, for strong acids and bases and neutral salts it does not express the facts. The author modifies it by writing

$$k=\frac{(\lambda_v/\lambda_\infty)^2}{\sqrt{v}(1-\lambda_v/\lambda_\infty)},$$

and then finds that, for many acids and salts, k depends only on the nature of the electrolyte and of the solvent, and is independent of the volume and temperature while the dilution varies from 4 to 128 litres. Analogous salts and acids of similar elements have nearly equal constants. A long series of tables are given, showing the molecular conductivities and constants of affinity of many electrolytes. W. C. D. W.

738. *Heat of Solution.* **H. Jahn.** (Zschr. phys. Chem. 17. pp. 550–551, 1895.)—The author points out that, in a paper by Rudolphi on the heat of solution and dissociation (Zschr. phys. Chem. 17. p. 277), the equation

$$-W_1=\frac{T^2}{C}\frac{\partial C}{\partial T},$$

giving the heat of solution (W_1) of a molecule of a solid in its saturated solution at a concentration C, is used for electrolytes. To these it does not apply, owing to the dissociation of the molecules into ions at the instant of solution. If C_1 denotes the concentration of the undissociated, and C_2 that of the dissociated portion, the author shows that the total heat developed by the solution of a molecule of an electrolyte is given by

$$L=-\frac{T^2}{C_1+C_2}\left(\frac{\partial C_1}{\partial T}+2\frac{\partial C_2}{\partial T}\right).$$

Values for the silver-salts of the acids of the acetic-acid series are given. W. C. D. W.

739. *Diffusion in a Cylinder of Finite Length under the Influence of Gravity.* **T. Des Coudres.** (Wied. Ann. 55. pp. 213–219, 1895.)—The author considers mathematically the effect of gravity in producing changes in the concentration of an originally uniform salt-solution contained in a vertical cylinder. Gravity tends to produce, and diffusion to destroy, these changes. If Δ_t and Δ_∞ are the differences in concentration at the two ends of a cylinder of length h at time t and after an infinite time respectively, and

a is the diffusivity of the salt, then approximately

$$\frac{\Delta_t}{\Delta_\infty} = \left\{ \frac{16at}{\pi h^2} \right\}^{\frac{1}{2}},$$

provided at/h^2 is small. The expression for Δ_∞ by itself involves quantities which cannot be experimentally determined.

G. F. C. S.

740. *Argon and Helium in Mineral Waters.* **C. Bouchard.** (C. R. 121. pp. 392–394, 1895.)—Certain alkaline mineral waters contaning sulphide and silicate of sodium, occurring on both sides of the Pyrenees, evolve fine bubbles of gas which are chiefly nitrogen. The author, in conjunction with Troost, collected some of these gases at Cauteret from various sources, dried them over potash and phosphorus-pentoxide, heated them for 48 hours over magnesium, and then passed the residue into Plücker tubes with magnesium wires, in which the nitrogen spectrum soon disappeared. The gas from the Raillère rivulet, spontaneously evolved or obtained by boiling, gave the argon and helium lines ; gas from the sources of the Bois only the helium lines ; gas from another (colder) spring of the latter rivulet, besides helium, certain red and orange lines of unknown origin. On the Spanish side, these waters are known as the Azoades, and their medicinal value used to be ascribed to the nitrogen. As argon is not found in all these gases, the author believes that it must partly come from the interior. Analyses of the waters are not given.

H. B.

741. *Combination of Argon and Helium with Magnesium.* **L. Troost** and **L. Ouvrard.** (C. R. 121. pp. 394–395, 1895.)—Experimenting with Bouchard's gas (see preceding Abstract), the authors find that it is unnecessary to heat the gases first over magnesium or lithium. They may at once be introduced into Plücker tubes, with magnesium wires connected to a Ruhmkorff with a Marcel Deprez interrupter. At first the absorption of nitrogen proceeds slowly. When, however, the electrodes begin to heat with decreasing pressure, the nitrogen combines rapidly with the magnesium vapours, which settle as a mirror on the glass. Fresh gas may be introduced when the nitrogen-lines have disappeared. If a strong discharge is maintained for several hours, however, both argon and helium appear to combine with the magnesium-vapour, and the lines begin to fade. Platinum electrodes cause a similar combination in an argon atmosphere. H. B.

742. *Colour of Ions.* **G. Magnanini.** (Rend. Acc. Linc. 4. 2, pp. 60–63, 1895.)—Experiments with violuric and dimethylvioluric acids and their potassium salts are favourable to Ostwald's theory of the colour of ions. So also are some observations with two other organic preparations which have acidic characters.

S. S.

CLARENDON PRESS LIST.

By Prof. W. W. Skeat, Litt.D.

In Six Vols. Demy 8vo, with Portrait and Facsimiles. £4 16*s.*

THE COMPLETE WORKS OF GEOFFREY CHAUCER. Edited from numerous MSS.

In Two Vols. Demy 8vo, uniform with the above. £1 11*s.* 6*d.*

PIERS THE PLOWMAN. Edited from numerous Manuscripts, with Preface, Notes, and Glossary.

In One Vol. Crown 8vo, Cloth. 7*s.* 6*d.*

THE STUDENT'S CHAUCER. Being a Complete Edition of his Works. Edited from numerous Manuscripts, with Introduction and Glossary.

"If the Library Edition of Prof. Skeat's 'Chaucer' is one which no gentleman's library should be without, the Student's Edition is one which every lover of literature should acquire."—*National Observer.*

THE OXFORD ENGLISH DICTIONARY.

New Parts recently published. 4to. Paper Covers.

A NEW ENGLISH DICTIONARY on HISTORICAL PRINCIPLES. Founded mainly on the Materials collected by the Philological Society.

D—Deceit. Edited by Dr. Murray. 3*s.* 6*d.*
Deceit-Deject. Edited by Dr. Murray. 2*s.* 6*d.*
F—Fang. Edited by Henry Bradley, M.A. 2*s.* 6*d.*
Fanged-Fee. Edited by Henry Bradley, M.A. 2*s.* 6*d.*

☞ The Delegates of the Press have arranged for the punctual issue of the letters D and F in Quarterly Sections. One Section at least, consisting of 64 pages, will be published quarterly at Half-a-crown.

6 vols. Medium 8vo, half-bound. £3 3*s.*

BOSWELL'S LIFE OF JOHNSON. With the Journal of a Tour to the Hebrides. Edited by G. Birkbeck Hill, D.C.L., Pembroke College.

2 vols. Medium 8vo, half-roan. 28*s.*

LETTERS OF SAMUEL JOHNSON, LL.D. Collected and edited by G. Birkbeck Hill, D.C.L.

FULL CLARENDON PRESS CATALOGUES POST FREE ON APPLICATION.

London:
HENRY FROWDE, Clarendon Press Warehouse, Amen Corner, E.C.

OPTICAL AND SCIENTIFIC INSTRUMENTS.

Spectrometers, Spectroscopes, Goniometers, Cathetometers, Optical Benches, &c., &c. Instruments for special purposes constructed to Clients' own designs. *Prices moderate. Price List free.*

W. WILSON (formerly Foreman at Messrs. Elliott Bros.),
56 CROGSLAND ROAD, CHALK FARM, N.W.

PUBLICATIONS OF THE PHYSICAL SOCIETY.

THE SCIENTIFIC PAPERS

OF THE LATE

SIR CHARLES WHEATSTONE, F.R.S.

Demy 8vo, cloth. Price 15*s.*; *to Members of the Society*, 7*s.* 6*d.*

Uniform with the above.

THE SCIENTIFIC PAPERS

OF

JAMES PRESCOTT JOULE, D.C.L., F.R.S.

Vol. I. 4 Plates and Portrait, price £1; to Members of the Society, 10*s.*

Vol. II. 3 Plates, price 12*s.*; to Members of the Society, 6*s.*

PHYSICAL MEMOIRS.

Part I.—Von Helmholtz, On the Chemical Relations of Electrical Currents. Pp. 110. *Price* 4*s.*; *to Members of the Society*, 3*s.*

Part II.—Hittorf, On the Conduction of Electricity in Gases; Puluj, On Radiant Electrode Matter. Pp. 222. *Price* 7*s.* 6*d.*; *to Members*, 5*s.* 8*d.*

Part III.—Van der Waals, On the Continuity of the Liquid and Gaseous States of Matter. Pp. 164. *Price* 6*s.*; *to Members*, 4*s.* 6*d.*

PROCEEDINGS.

To Members of the Society only, at the following prices:—

Vols. I.–IV. 2 vols., cloth, 25*s.*, unbound 23*s.*

Vols. V. & VI. 1 vol., cloth, 13*s.*, unbound 11*s.*

Vols. VII. & VIII. 1 vol., cloth, 13*s.*, unbound 11*s.*

Vols. IX. & X. 1 vol., cloth, 16*s.*, unbound 14*s.*

Vols. XI. & XII. 1 vol., cloth, 16*s.*, unbound 14*s.*

These prices do not include carriage.

Applications for these Vols. must be sent direct to

Taylor and Francis, Red Lion Court, Fleet Street, E.C.

INDEX TO ABSTRACTS.

GENERAL PHYSICS.

Page
694. Observation of Torsional Vibrations. *R. W. Wood* 427
695. Compressibility of Solutions. *G. Tammann* 428
696. Plasticity of Ice. *O. Mügge* 429
697. Theory of Gases and Liquids. *G. Bakker* 429
698. Influence of Pressure on the Electric Conductivity of Solutions. *G. Tammann* 430
699. Stresses produced in a Continuous Girder owing to Differences of Temperature between the Flanges. *Deslandres.*—Note on the preceding. *M. Lévy* 431
700. Mont Blanc Observatory in 1895. *J. Janssen*.............................. 431
701. Comparisons of Length. *B. Pensky*.. 431
702. Viscosity and Conductivity of Amalgams. *E. R. v. Schweidler* 432
703. Van der Waals' Thermodynamic Theory of Capillarity. *W. Sutherland*.. 432
704. Vibrationless Supports for Instruments. *W. H. Julius*.................. 432
705. Vibrationless Supports for Instruments. *W. Einthoven* 433
706. Determination of the Density of Gases. *H. Moissan & H. Gautier* ... 433
707. Critical State. *K. Wesendonck*.. 434
708. Solubility of Hydrated Mixed Crystals. *W. Stortenbeker* 434
709. Organic Developers of the Latent Photographic Image. *A. & L. Lumière* 434
710. Electrical Conductivity of Palladium-Hydrogen in Relation to its Dissociation-Pressure. *A. Krakau*.. 434

LIGHT.

711. Absorption-Spectrum of Water, and the Tissues of the Eye. *E. Aschkinass* 436
712. Lighting by means of Incandescent Gases. *C. E. Guillaume* 436

HEAT.

713. Calculation of the Heat of Solution from the Solubility. *J. J. van Laar* 437
714. Critical Temperature and Boiling-Point of Hydrogen. *K. Olszewski* 437

[*Continued over-leaf.*

INDEX (*continued*).

SOUND.

Page
715. Resonance. *Neyreneuf* 439
716. Siren. *H. Pellat* 439

ELECTRICITY.

717. Electrical Conductivity of Salts in various Solvents. *C. Cattaneo* ... 440
718. Fall of Potential in a Three-Phase Circuit. *J. Rodet* 440
719. Reverberatory Electric Furnaces. *H. Moissan* 440
720. Holtz Influence Machine. *K. E. F. Schmidt & H. Rühlmann* 442
721. Magnetic State of the Planets. *E. Leyst* 442
722. Conductivity of Mixtures of Metallic Filings and Dielectrics. *G. T. Lhuillier* 443
723. Sources of Error in very Sensitive Apparatus. *H. Armagnat* 443
724. Electric Discharge in Gases. *O. Lehmann* 445
725. Electrolytic Conductivity of Concentrated Sulphuric Acid. *K. E. Guthe & L. J. Briggs* 445
726. Distribution and the Secular Variation of Terrestrial Magnetism. (I.) *L. A. Bauer* 447
727. Compounding Dynamos for Armature Reaction. *E. Thomson* 447
728. Double Refraction of Electric Radiation. *P. Lebedew* 447
729. Phasing Transformers. *C. S. Bradley* 449
730. Magnetism of Iron Cylinders. *Ascoli* 450
731. Secular Motion of a Free Magnetic Needle. *L. A. Bauer* 450
732. General Alternate-Current Transformer. *C. P. Steinmetz* 450
733. Magnetism of Volcanic Rocks. *C. Folgheraiter* 452
734. The Earth a Magnetic Shell. *F. H. Bigelow* 453

CHEMICAL PHYSICS.

735. Effect of Centrifugal Force upon Chemical Systems. *G. Bredig* 454
736. Amalgams of Iron. *A. Zamboni* 454
737. Ostwald's Formula for Constants of Affinity. *M. Rudolphi* 454
738. Heat of Solution. *H. Jahn* 455
739. Diffusion in a Cylinder of Finite Length under the Influence of Gravity. *T. Des Coudres* 455
740. Argon and Helium in Mineral Waters. *C. Bouchard* 456
741. Combination of Argon and Helium with Magnesium. *L. Troost & L. Ouvrard* 456
742. Colour of Ions. *G. Magnanini* 456